ILLUMINATING ENGINEERING

FEBRUARY 1952

Fluorescent Luminaire Candlepower Distribution
Recommended Practice for Sports Lighting—II
Tests of De-Staticizers on Polystyrene
Visual Problems in Aircraft Lighting
Designs for Home Lighting Education
Study of Orange Surface Colors

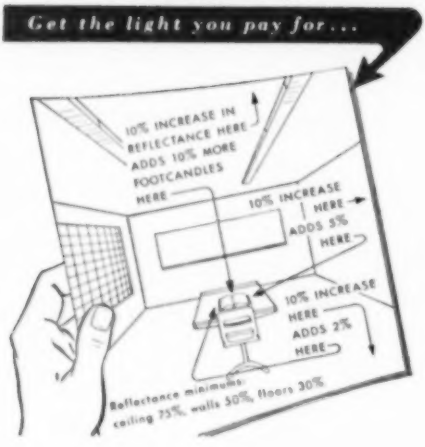
THE JOURNAL OF THE ILLUMINATING ENGINEERING SOCIETY

One of Several Classrooms

Library and Study Room

Basic Chemistry and Science Laboratory

Nutrition Laboratory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Architect Chooses *Wakefield* Grenadiers for School of Nursing

Hampson and Fisher, architects
Springfield Electric Company, electrical contractor

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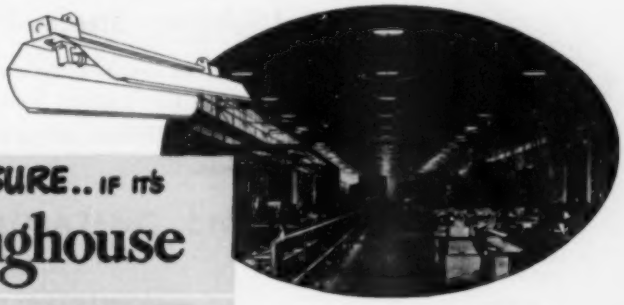

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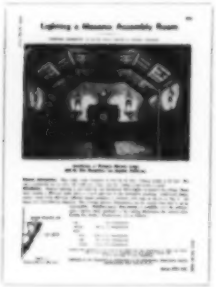

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ILLUMINATING ENGINEERING

THE JOURNAL OF THE ILLUMINATING ENGINEERING SOCIETY

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Brightness Patterns on Pavements With Elongated Light Sources

By LOUIS J. SCHRENK

THIS study is based on observations and photographs of fluorescent and modern filament street lighting installations in the City of Detroit. On wet pavements, the elongated fluorescent luminaires give reflected brightness patterns on the roadway that are much broader and cover a greater area than those from the more concentrated filament sources, with their relatively small light controlling auxiliaries (reflectors, prismatic glassware, etc.). On dry, worn pavements, where as a rule there is an element of specularity, the fluorescent units compare most favorably also. The design of the fluorescent luminaires with appropriate light control giving asymmetric light distribution, makes it possible to mount them with less overhang. This adds to the pavement brightness near the curb, and makes the overall brightness more uniform. In addition, the fluorescent luminaire is a large source of relatively low brightness, as compared with the typical filament luminaire, and minimizes discomfort glare in the driver's or pedestrian's field of view.

Do elongated light sources have an inherent advantage in street lighting? This question has been given much study. Several years ago, the Illuminating Engineering Society sponsored experimental installations in Detroit, Cleveland and Schenectady.* The City of Detroit has set up the first fluorescent installations in this country to conform to the American Standard Practice for Street and Highway Lighting. The accompanying Detroit photographs show these installations and compare them with present day filament luminaires. Now, for the first time, we can study the brightness patterns from such elongated luminaires, on both wet and dry pavements.

The units we are comparing are (1) a typical modern pendent filament lamp luminaire with asymmetric distribution, (2) an experimental fluorescent lamp luminaire with no transverse or vertical light control, and (3) a fluorescent lamp luminaire *with* both transverse and vertical light control to yield an asymmetric distribution. These three luminaires are shown in Fig. 1, and their candlepower distribution curves are shown in Fig. 2. Luminaire No. 2 consists simply of three 8-foot T-12 fluorescent lamps in a vertical row, mounted crosswise to the roadway. Luminaire No. 3 consists of twin luminaires back-to-back in a horizontal "V" positioned at 30 degrees with the vertex pointed out across the street to direct the light away from the curb and into the roadway. Each of the twin luminaires employs two 8-foot T-12 lamps in a reflector which redirects the light out at wide vertical angles. They also employ Alzak reflectors having a contour such that the candlepower is materially increased and at the same time partial shielding of the sources is obtained.

Wet pavement conditions have always been the most critical from the standpoint of street lighting effectiveness. The largely diffuse reflecting properties of the dry pavement are changed, and the luminaires' reflections with filament sources tend to become only narrow, bright streaks on the street surface. In addition, driving is more hazardous on the slippery streets, and seeing is reduced by wet windshields.

Fig. 3 shows all three installations with pavement inundated. The differences in patterns of pavement brightness, comparing the two examples of elongated sources with the single typical example of the smaller sources are striking.

Patterns of Pavement Brightness

These typical reflection patterns with the filament luminaires are so bright as to be sources of reflected glare to the eyes both of drivers and of pedestrians. The longer fluorescent luminaires, on the other hand, give rise to pavement brightness patterns that are much broader and of lower brightness. The sensation of glare is reduced, and the observer's impression is that the installation is, in general, more comfortable. The fluorescent lighting, particularly in the installation of No. 3, retains its dry weather effectiveness much more completely with wet pavement than other types of installa-

A paper presented at the National Technical Conference of the Illuminating Engineering Society, August 27-30, 1951, Washington, D. C. Author: Public Lighting Commission, City of Detroit.

*Studies of Fluorescent Street Lighting, Illuminating Engineering Society, Vol. XLI, No. 2, Feb. 1946.

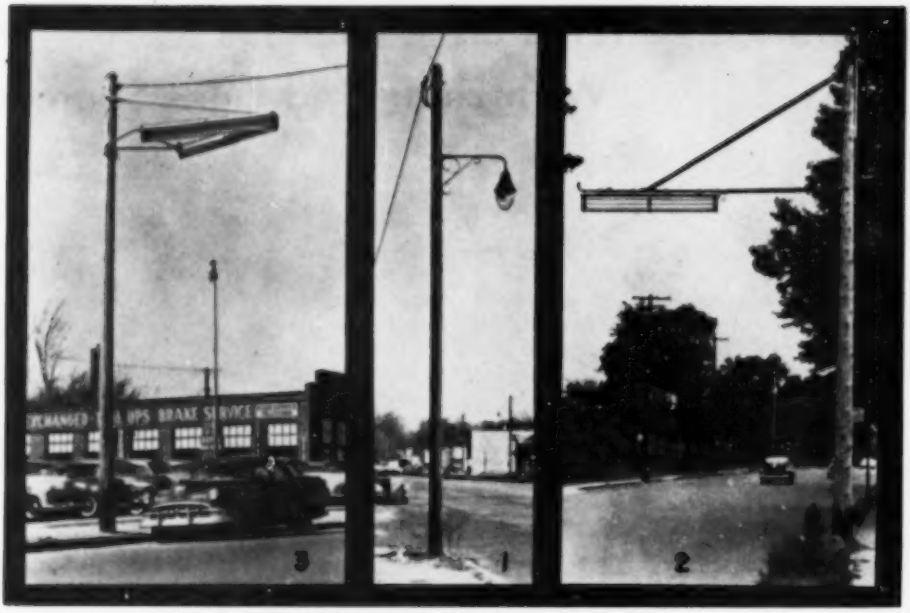


Figure 1. Daytime views of the three street lighting units.

(a) Filament luminaire, No. 1 (center), typical of present day units, 2 feet from curb. Mounting height 25 feet, average spacing 160 feet.

(b) Fluorescent luminaires, No. 2 (right), of experimentaltype with no light control. Nearest end, 8 feet from curb containing three 8-foot T-12 lamps. Mounting height 25 feet, average spacing 160 feet.

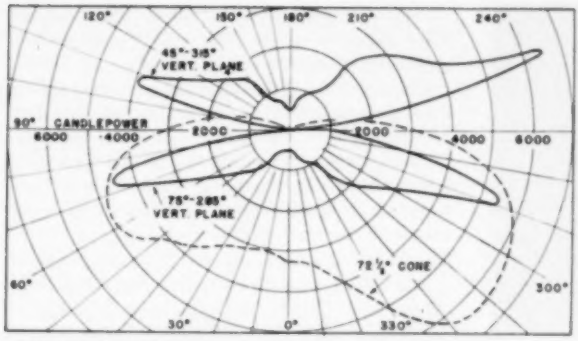
(c) Fluorescent luminaire, No. 3 (left), mounted in pairs and giving vertical and transverse light control. Nearest ends of luminaires, 2 feet from curb. Four 8-foot T-12 lamps, two in each luminaire. Mounting height 25 feet, average spacing 140 feet.

tions. Since seeing at night is predominantly by contrast, visibility is greatly enhanced under all conditions.

There *is* a difference, however, although perhaps not so marked as between the filament and fluorescent lamp installations — between the individual appearances of the two fluorescent installations. The pavement brightness pattern of No. 2 still shows fairly bright strips, limited in width, leaving continuous dark areas along the curbs. But with the fluorescent units of No. 3, we see the reflections as broad paths, practically filling the roadway with reflected brightness from curb to curb.

The photographs make it plain why we have this difference between the brightness patterns from the types of fluorescent units. Luminaire No. 2 overhangs the curb by 16 feet, of which 8 feet is the luminaire's length. This means that as we view the street from the average driver's eye position in the right-hand driving lane (the second lane from the curb), the luminaires on the right-hand side are directly in front of us, and their reflections merge into a single continuous path straight ahead. Luminaire No. 3, on the other hand, has been mounted closer to the curb, overhanging by only 10 feet, of which 8 feet is the luminaire's length. In this case the right-hand row of luminaires passes over us *at the side*, rather than directly *above* us as with No. 2. So the reflections from the farther ones appear progressively farther into the center of the roadway. In fact, if the installation were not limited in its length, the right- and left-hand rows would join at the distant vanishing point, and the path of lower brightness down the center of the pavement would be somewhat brighter. This effect can be seen in the photograph of the lengthier installation of No. 1.

The advantage of No. 3 is a result of its directional light control and its asymmetric distribution, which makes it feasible to mount it close to the curb. If the same were tried with No. 2, much of



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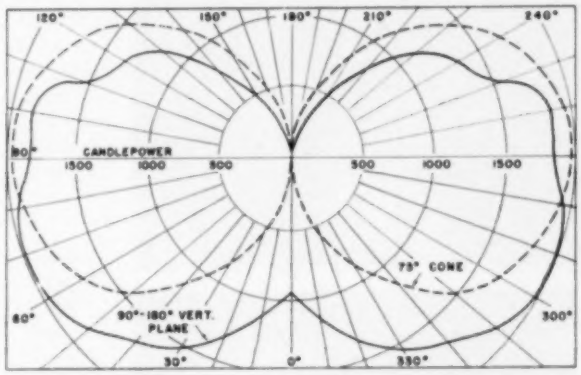
NO. 193 CLEAR RIPPLED GLOBE

SCOOP REFLECTOR
10,000 LUMEN BI-POST 20 AMP. LAMP
FILAMENT AT 45°

Figure 2. Distribution curves of the three units shown in Fig. 1:

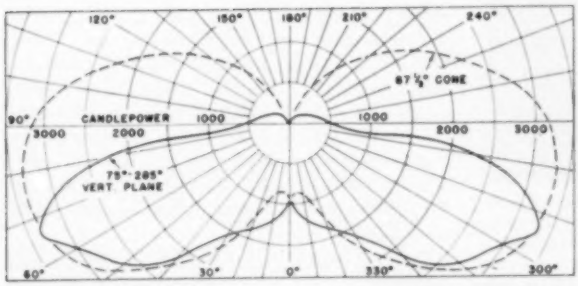
(a) Filament luminaire N. 1 shows the vertical and lateral distribution. The luminaire is mounted at or near the curb and is designed to give a wide unequal lateral distribution to direct the greater part of the light output in the direction of the oncoming traffic, resulting in an unbalanced asymmetric distribution. The maximum candlepower is directed in the 315° vertical plane to build up the illumination in the center of wide thoroughfares.



CANDLEPOWER DISTRIBUTION
CITY OF DETROIT FLUORESCENT LUMINAIRE

3-96" SLIMLINE LAMPS (T-12)
MOUNTED IN VERTICAL PLANE

(b) Fluorescent luminaire No. 2 shows a wide two-way distribution for mounting well out in the street.



CANDLEPOWER DISTRIBUTION
G.E. FORM 200 B FLUORESCENT LUMINAIRE
POLISHED "ALZAK" TROUGH REFLECTOR

PLASTIC CLEAR COVER GLASS
4-96" SLIMLINE LAMPS (T-12)

(c) Fluorescent luminaires No. 3 show a wide asymmetric distribution for mounting near the curb. Two two luminaires if placed back to back would give a two-way distribution; however, in the present installation they are placed at a 30° angle with each other to direct the light toward the center of the street.

its light would be wasted on the house side of the curb, and its coefficient of utilization would suffer.

Slight irregularities in the wet pavement surface are of special help, and it may well be that the asymmetric distribution of No. 3 takes better advantage of these. This effect would depend upon the degree to which the installation of No. 3 puts more uniform footcandles upon the roadway than does the installation of No. 2.

It must be borne in mind that there is a difference in illumination levels of the two fluorescent installations shown here, as this might affect one's

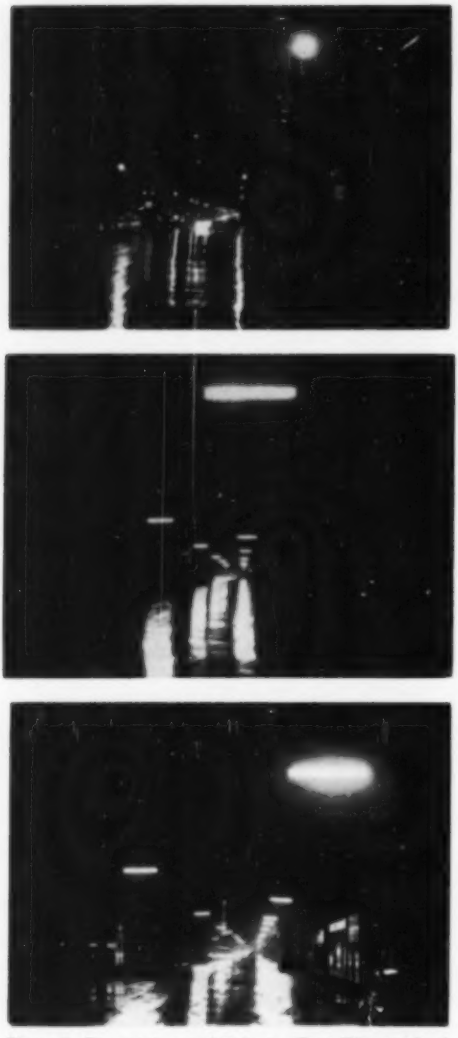


Figure 3. Pavements inundated. A. (Top) Filament luminaire No. 1. Bright narrow streaks of reflection on pavement. B. (Center) Fluorescent luminaire No. 2. Wider strips, less bright. More area filled with brightness; still very little brightness near curb. C. (Bottom) Fluorescent luminaires No. 3. Broad bands of reflected brightness; better uniformity over entire width of roadway. Shorter overhang; reflected brightness extending completely over to curb.

appraisal of the photographs. Installation No. 2 has an average of between 0.5 and 0.7 footcandles and No. 3 has 1.0 footcandle, or slightly higher, based on initial lumens.

When the pavement is dry, we see much less difference between the pavement brightness patterns. These appear in Fig. 4.

Comparing the filament installation with the two fluorescent installations, we see at once that the pavement brightness is more uniform under the last two. This is true even though the fluorescent installation of No. 2 actually has a lower *average* pavement brightness and illumination than the filament installation of No. 1.

But again, we see marked differences between the two fluorescent installations. That of No. 3 shows better brightness uniformity than that of No. 2, both along the roadway and across it. And the curb is more clearly defined in No. 3. As with the wet pavement condition, if we tried to aid the brightness in the parking lane by moving the units of No. 2 closer to the curb, we would sacrifice some of the brightness which is needed in the center of the street.

As would be expected, the brightness patterns with the pavements damp are intermediate between those with the pavements wet and dry. This is shown in Fig. 5.

Temperatures-Light Output Characteristics

Starting in 1945 and for two years thereafter, Detroit experimented with a multiple circuit for fluorescent street lighting. The lighting effects were favorable during the greater part of the year, however, during cold weather, the light output was very poor. The fluorescent lamps were enclosed in protective tubing and the breakage was extremely high. The installation was removed as it was considered too expensive to maintain and its operation during cold weather was unsatisfactory. Detroit felt that a fluorescent street lighting installation might be acceptable by using a series street lighting circuit. It was felt that this would give a reasonably stable light output through the variable temperatures of a Detroit winter and summer season, or the current could be varied to partly compensate for the loss in light output during adverse weather conditions.

Starting experiences of the twin luminaires while operating the lamps at 430 milli-amps was satisfactory until the temperature dropped to 15°F; below that, starting troubles began. The constant current regulator was adjusted for operating at 660 milli-amps. The change provided sufficient voltage so that no starting troubles were experienced down to −5°F. This was the minimum operating temperature experienced through the winter. Light output at 430 milli-amps and 15° is reduced approximately 70 per cent and at 660

milli-amps the reduction is approximately 50 per cent.

The light output was measured with a continuous recording of a photo-electric cell. There have been no lamp outages due to equipment, lamps, or circuit trouble for the entire 2000 hours this installation has been in operation. The lumen output of the T-12 fluorescent lamps was reduced to 84 per cent of the initial output after 2000 burning hours. The preliminary test in severe cold weather indicated that the manufacturer may have to furnish a special lamp for street lighting purposes.

Comparison of Installation Costs

The installation cost for both types of lighting are the same up to and including the lamp post. A tabulation of the different costs is shown in Tables I and II.

TABLE I.—Installation Costs.

	Filament Lamp	Fluorescent Lamp
Luminaire & Bracket	$ 53.38	$175.00
Auxiliary transformer	49.50	80.00 (2 @ $40 ea.)
Lamps	1.65 (bi-post)	7.80 (4 T-12)
Installation of luminaire	8.00	24.00
	$112.53	$286.80
Other capital cost common to both	150.00	150.00
Initial lumen output	10,000	18,000 — 430 MA 23,000 — 660 MA
Effective lumens (calculated)	4,800	7,020 — 430 MA 9,000 — 660 MA
Watts including auxiliaries	541	390 — 430 MA 560 — 660 MA
Lumens/watts	18.5	46 — 430 MA 41 — 660 MA

TABLE II.—Annual Operating Costs.

	Filament Lamp 10,000 Lumen	Fluorescent Lamp Based on 430 MA Operation
Fixed charges on investment common to both lamps	$13.43	$13.43
Operating costs common to both lamps	13.57	13.57
Depreciation and interest on the variable costs—6%	6.75	17.21
Yearly cost on cleaning and relamping	.95	5.70
Lamps	(2) 3.30	(4) 7.80 (est.*)
Cost of current @ 1 cent per KWH	21.64	15.60
	$59.64	$73.31
Cost of effective lumen per year	$ .01242	$ .01044

Although the initial installation cost is considerably higher for the fluorescent luminaires, the annual operating unit cost based on effective lumens is lower.
*Installation in operation one-half year.

Figure 4. Pavements dry. A. (Top) Filament luminaire No. 1. Brightness still somewhat spotty. B. (Center) Fluorescent luminaire No. 2. Lower average brightness than with No. 1, but better uniformity than filament lighting. Still some rather dark areas near curb. C. (Bottom) Fluorescent luminaires No. 3. Much better uniformity, especially with areas near curb.

Night Driving and Public Opinion of Fluorescent Street Lighting

Visibility is exceptionally good and the installation provides comfortable seeing. There is no noticeable glare when spoken of in terms of "discomfort or veiling glare." A driver while passing through either of the two types of installations can view the luminaires without discomfort to the eyes.

There has been some complaint from drivers which could be termed "distraction." However, it is felt that this is due to the innovation of a new type of street lighting and will eventually wear

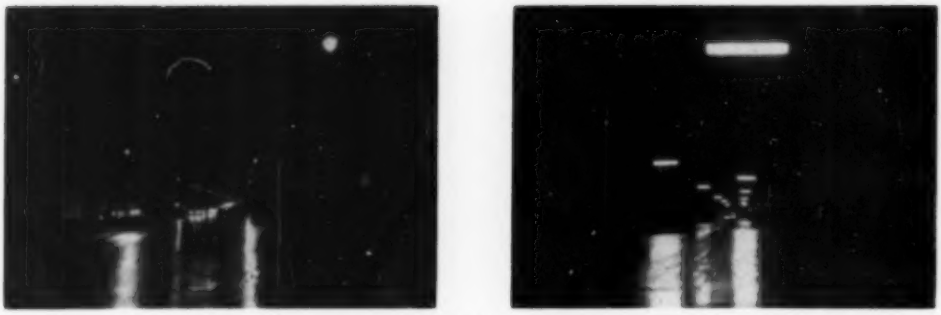


Figure 5. Pavement damp but not inundated. More area is filled with brightness with all luminaires and the brightness pattern increases as the pavement dries out.

A. (Left) Filament luminaire No. 1. **B. (Right) Fluorescent luminaire No. 2.**

away. The great majority of drivers and pedestrians have complimented the lighting effect very highly. The lighting has also met with universal favor among the property owners. Other business sections have been quite inquisitive as to possibilities of future extensions. There has been no adverse comments from any of the adjacent property owners.

Future Lighting

Street lighting in general with few exceptions does not adequately meet the night traffic problems under all conditions of road surfaces and weather. Due to our complex mode of living, night traffic volumes, both vehicular and pedestrian are constantly increasing and during the rush hours in the winter months, it equals the daytime movement. Statistics show that the number of night traffic accidents are far too many when compared on the basis of day and night traffic volumes. Easy and quick seeing provided by daylight should be more nearly approached with the use of artificial lighting if the problem of providing safer night travel is to be solved. Street illumination should reveal the entire road with the light extending well over the curb. This can only be done by distributing sufficient light sources transversely over the roadway, especially when pavements are highly specular.

The experimental fluorescent lighting installations in Detroit are an attempt to provide just such ilumination. The twin luminaire fluorescent installation with its asymmetric distribution, long light sources of low brightness, comfortable to the eye is a most promising step forward in providing visibility on both wet and dry pavements, more nearly approaching that under daylight conditions. These results are not obtainable with the point light source.

Lighting for "Zebras"

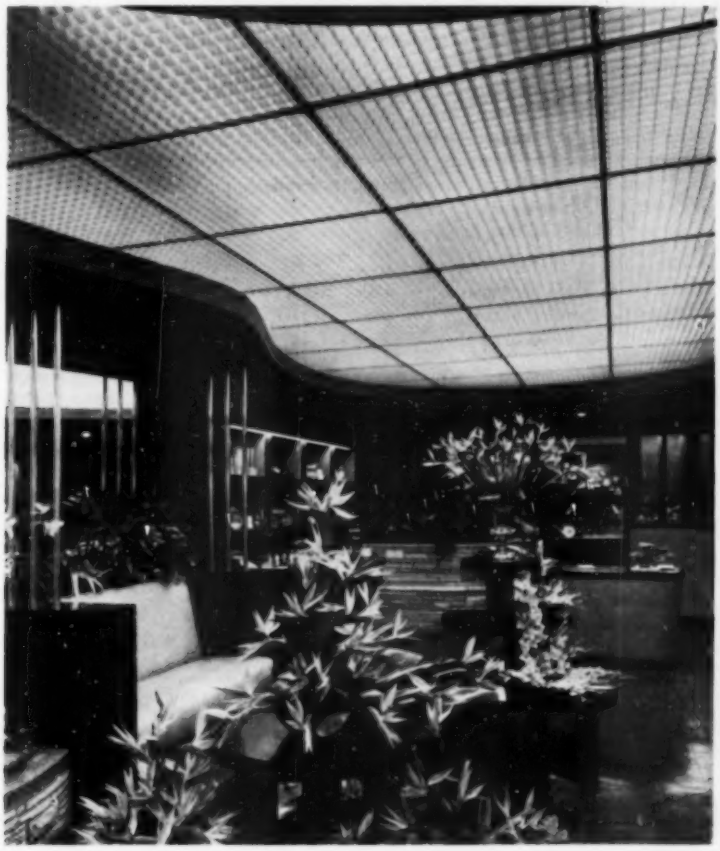
Most pedestrians in this country, accustomed to leaping to safety before the insistent honks of taxis, buses, trucks and private automobiles, would appreciate an innovation which is causing much controversy in London. This is the painting, at intersections, of wide passages with white stripes, known as "zebras," upon which the pedestrian may cross, and upon which a motorist dare not trespass during such a crossing.

The controversy is caused, in part, by complaints from motorists that on wet nights the zebras are all but invisible. Their stripes blend with the shining road surface. "Lumenatas," in *Light and Lighting*, journal of the British I.E.S., says: "A tour of one London borough has convinced me that the crossings cannot be seen from an approaching car on a wet night. So far I have noticed illuminated beacons at one crossing only, and I doubt if they will prove sufficiently conspicuous markers in thoroughfares where there are numerous other lights. The Minister of Transport has said that methods of revealing the crossings to road users at night are being tried, and it is to be hoped that a satisfactory solution of this problem of lighting will soon be found. The Twickenham Road Safety Vigilantes' Association has suggested the use of flickering amber warning lights in advance of traffic signal lights on high-speed roads. I think such flickering lights might be used to better purpose at 'Zebra' crossings."

Street lighting engineers the world over will probably watch with interest the way in which London solves this problem of lighting for "zebras."

Louverall Lighting for a Florist Shop

LIGHTING OBJECTIVE: To provide general lighting in a long, narrow, high-ceiling room to enhance the attractiveness of floral displays, at the same time concealing unsightly pipes and ducts.



Installation at The Broadway Florist, 218 West 5th Street, Los Angeles, California.

General Information: Figure 2 shows a plan view of the sales area. Ceiling height is 20½ feet. Surface characteristics are as follows:

Walls and trim	dark green	7% RF
Canopy		
vertical trim	light green	35% RF
Ceiling		
under canopy	green acoustical tile	35% RF
Display niches	dark green	7% RF
Floor	mottled green rubber tile	12% RF

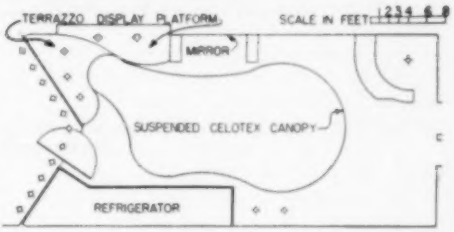


Figure 2. Plan View.

(over)

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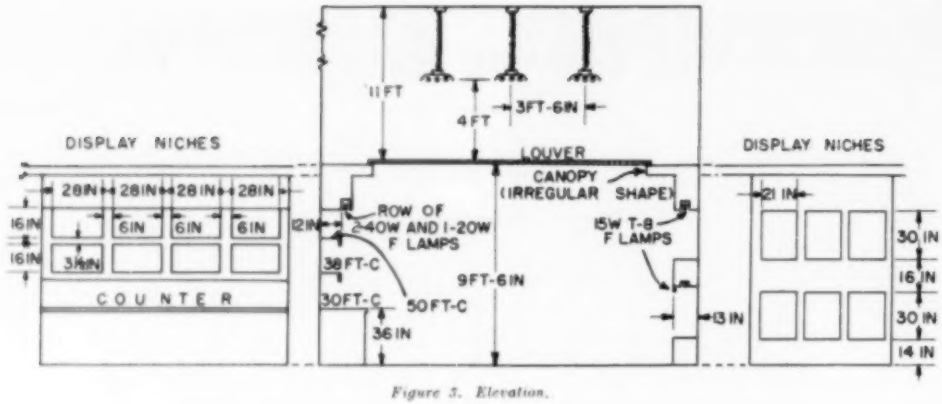

Figure 3. Elevation.

The eight niches shown at the left measure 16 x 28 inches. Those at the right are constructed with a sawtooth effect: the farther group of two protruding further into the store area than the one adjacent to it.

The area in the rear of the photograph is the wrapping section. Behind the vertical wood louvers is a customer room with table and card writing facilities.

Lighting Installation: A general illumination level of 95 footcandles is provided by continuous rows of industrial fluorescent luminaires spaced 3½ feet apart and mounted 4 feet above Benjamin "Skyglow" plastic louvers (2 x 2 x 2 inch cells, 9½ feet above floor and 11 feet below structural ceiling). Each luminaire contains three 40-watt warmtone lamps. Industrial units were chosen to direct light away from pipes, beams, etc. above the louvers.

Display highlights of 200 footcandles are supplied by recessed 150-watt R-40 spotlamps. The refrigerator at the right (not shown in photo) also has a louvered ceiling, covering up the pipes, condenser, etc.

The niches shown on the left in the photo are illuminated by a strip of two 40-watt and one 20-watt T-12 fluorescent lamps, providing 50 footcandles on the top shelf, 38 footcandles on the center one and 30 footcandles on the counter. Each right niche is illuminated by a 15-watt fluorescent lamp.

The mirror at the left (behind the davenport) gives the illusion of a cove, or extended part of the general room.

Resultant brightnesses are indicated below:

	footlamberts
Louvers	
45°	120
30°	90
Walls near ceiling	3.5
Canopy (vertical edge)	7.0
Ceiling under canopy	0.8
Floor	1.6

Lighting data submitted by Illuminating Engineering Unit, Department of Water and Power, City of Los Angeles as an example of good lighting practice and to aid in the design of similar installations.

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Visual Problems in Aircraft Lighting

By FRED R. BROWN
DAVID ALSHER

IN RECENT years in the field of equipment design there has been increased emphasis upon the point of view which recognizes the human being as a critical link in the control system. Formerly, the assumption was made that man had the potential for sufficient training to operate machines designed with only incidental adaptation to his requirements. However, the greater complexity of modern machines, as typified by higher performance aircraft, has required responses near the physiological and psychological limits of the human operator. This is particularly the case with military aircraft where the environment is extremely different from the normal. Military flying in recent times has been characterized not only by problems incident to high speed and acceleration, extreme temperatures, high altitudes, noise and vibration but also by greater difficulties in perceiving and responding to many visual stimuli.

Visibility Problems

It is evident, therefore, why visibility problems, particularly lighting problems, assume such importance in aviation. Obviously, every measure which improves the efficiency of the pilot's seeing task adds considerably to his comfort and morale and to the military value of his performance.

Although their solution cannot be separated completely from the solution of other problems in aircraft design, lighting design problems constitute a fairly well defined and rather distinct area of interest. Aircraft lighting is one aspect of the larger problem of aviation lighting which includes such other matters as airport and airway lighting. As applied to aircraft, the field can be subdivided into interior and exterior lighting.

Cockpit Lighting

A primary concern in the study of interior lighting is the job of illuminating aircraft cockpits. About seven years ago the Navy became interested in the possibility that red lighting might be a better form of cockpit lighting than the ultraviolet lighting of fluorescent painted instruments then in vogue. It is known that red lighting is advantageous for promoting dark adaptation. Reports from operational personnel indicated that night missions of naval aircraft would be aided if the pilots had a maximum amount of dark adaptation in order to detect dimly illuminated targets. As a consequence, an investigation was initiated at the Fels Planetarium of the Franklin Institute in Philadelphia to procure definite information on the relative advantages of red lighting and ultraviolet. Two Link Trainers were provided with the best available systems of red indirect, false panel lighting and ultraviolet flood lighting. Pilots were given flight problems to perform in either the red or the U-V illuminated trainers. Under Planetarium conditions approximating starlight and overcast night sky illumination, a comparison was made of the time required to spot faint targets against the sky background after having been exposed to one or the other instrument panels. It was found that at the brightness levels giving minimum legibility, neither system caused any noticeable decrease in the efficiency of spotting. However, at higher, more useful levels of brightness, there was greater detectability of targets after viewing the red panels (Table I).

In addition to those studies simulating the practical problem, a Hecht-Shlaer adaptometer was used to obtain more precise data on the course of dark adaptation during exposure to the alternative lighting techniques. Since these data also supported the advantage of red lighting, the Navy adopted a system employing a tailor-made false panel to illuminate indirectly the entire instrument panel. In the fall of 1949 the Navy and Air Force cooperated in conducting an evaluation tour to gather opinions from Navy and Air Force pilots on their subjective preferences for the red lighting system versus the ultraviolet system then being used by the Air Force. Similar military planes, each employing one of the lighting systems, were flown by Navy and Air Force pilots. As a result of this tour in which a majority of the pilots preferred the red lighting system, this system became standard for both services.

In subsequent experimental work, as described below, efforts have been directed to developing criteria, based on physiological and psychological

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The views expressed in this paper are those of the authors and are not intended to represent those of the Department of the Navy.

TABLE I.—Spotting-Time Experiments.

Percentage of Trials in Which Target Was Spotted in Four Seconds or Less.

Sky Condition	Panel Setting	No. of Subjects	Control*	Red	Efficiency Red % / Control %	Control†	U-V	Efficiency U-V % / Control %
			%	%		%	%	
Starlight	Dim	5	47	45	0.97	51	44	0.87
Overcast	Dim	5	59	63	1.04	47	38	0.77
Starlight	Bright	5	53	44	0.83	41	12	0.29
Overcast	Bright	6	43	39	0.90	63	24	0.38

*Same test condition as for red lighting except that instrument panel was not illuminated.
†Same test condition as for U-V except that instrument panel was not illuminated.

studies, to be applied in the design of fixtures and techniques utilizing red lighting. The desirability of reducing flux in order to facilitate further dark adaptation has led to the investigation of indirect methods of lighting.

Instrument Lighting

With respect to aircraft instruments, there has been a progressive development toward the use of individual shields providing illumination from covered sources in front of the upper corners of each instrument (Fig. 1).

Although the lighting produced by these shields is fairly uniform and causes a minimum of reflections from the canopy, nevertheless certain instruments show distinctly decreased levels of legibility. The turn and bank indicator is a notable example requiring modification for use with the lighting shield. In the conventional form, this instrument requires the incident light to be nearly perpendicular to the surface, so that the high reflecting background is sufficiently illuminated to provide high contrast for the black ball. The solution devised by our laboratory is to reverse the contrast by using a white ball with black background and to recess the dial, thus making use of the light directed almost vertically from the shield (Fig. 2). Many other instruments require similar modification to provide the required contrast for adequate legibility.

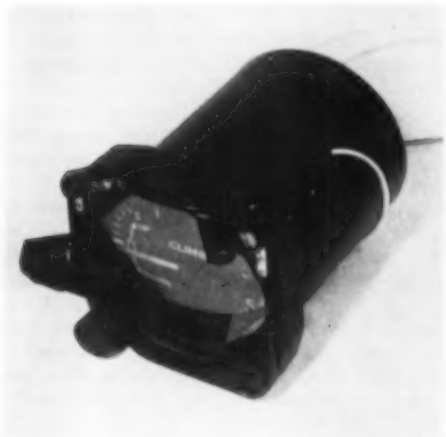


Figure 1. Aircraft instrument with individual lighting shield providing illumination from covered sources in upper corners.

The desirability of integral instrument lighting has been repeatedly expressed over a period of years. The obvious advantage accruing from building each instrument with its own light is that its unique legibility requirements will be met. Such lighting will yield higher levels of legibility and greater uniformity of illumination, and eliminate cover glass reflections, a most troublesome aspect of instrument lighting. Developments to reach this objective have been initiated. A present instance of an integrally lighted instrument is the magnetic compass.

Control Panel Lighting

Panels containing switch controls also must be effectively illuminated. A development in lighting these control panels, which are grouped into consoles in the cockpit, has been the edge lighting of plastic plates. The top surface is covered over-all first with a translucent white paint and then with a negative opaque print in black. The other surfaces including holes for switches and knobs may be painted white followed by black. By this process a console is produced which has white markings in a black field during daytime. For night viewing, red-filtered lighting is piped from fixtures strategically located on the panel. Such transillumination yields unusually high contrasts resulting in new legibility problems. (Fig. 3).

The entire question of the legibility of the markings on these consoles was studied in several aspects. In connection with marking design and layout, a study has been made of the legibility characteristics both of daylighted and transilluminated markings, letters, and numerals. Size, brightness, contrast, and form were some of the variable characteristics studied. For the study of these characteristics, under night illumination conditions, a special visual test enclosure simulat-

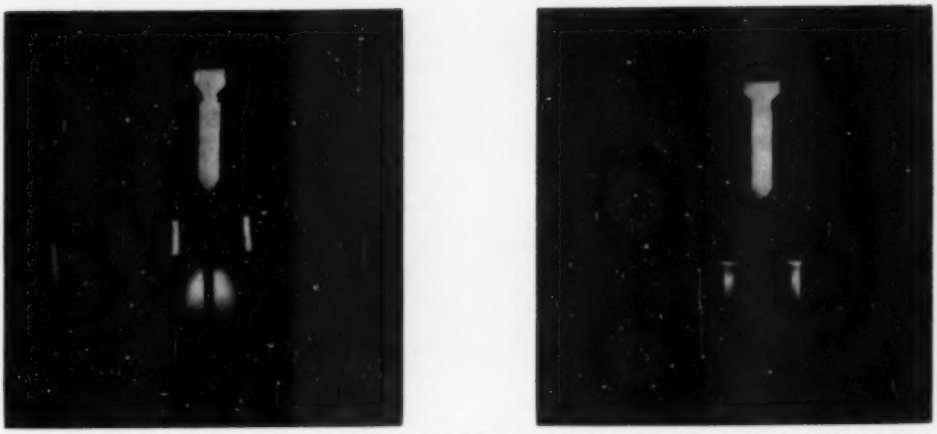


Figure 2. Turn and bank indicator. At left, instrument modified for use with the lighting shield. Contrast is reversed and dial recessed compared with unmodified instrument shown at right.

ing a cockpit reading situation was constructed (Fig. 4). This enclosure is light-tight and contains floodlighting fixtures and controllable light which can be directed from the rear on a translucent card. This card can then be viewed by a subject sitting at a prescribed distance. Naval enlisted men were dark adapted, seated in this enclosure and asked to read letters at different brightnesses with short exposure times.

Test results show that legibility improves with increasing size and brightness with different effects, however, for letters of different form (Fig. 5). To avoid loss of legibility of some markings while others are still adequately visible and to limit the total light flux, it has been recommended that all lettering be of uniform size and brightness on consoles. Other marking characteristics found to increase legibility are uniform stroke-width, lack of serifs, and square rather than rounded stroke ends. Height to width ratio and stroke-width to height ratio were explored for both letters and numerals, and optimal ratios recommended for use with transillumination. Even though letter strokes should be relatively narrow (one-tenth or less of height) for transillumination when high brightnesses are used, we have shown in our legibility experiments that when brightnesses are reduced to the level required for preserving dark adaptation, wider strokes (one-sixth of height) give letters optimal legibility for both day and night use (Figs. 6, 7, 8). Commercial type faces most nearly agreeing with the qualities of legibility thus far determined as most suitable by our experiments are Airport Semi-Bold, Futura Demi-Bold and Vogue Medium. A series of numerals incorporating our experimental findings have been designed by laboratory personnel (Fig. 9). Validation tests show that, in comparison with

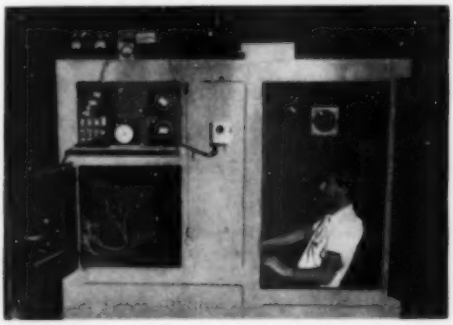


Figure 3. (left) Transillumination of control panel. Figure 4. (right) Visual test enclosure simulating a nighttime cockpit reading situation for study of legibility of marking characteristics.

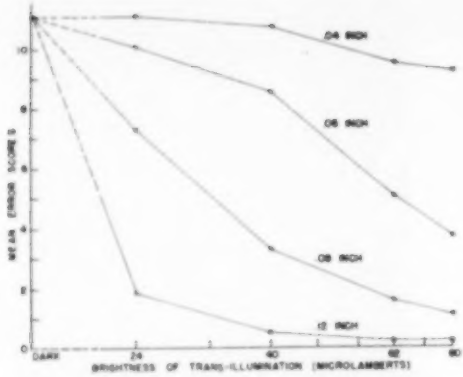


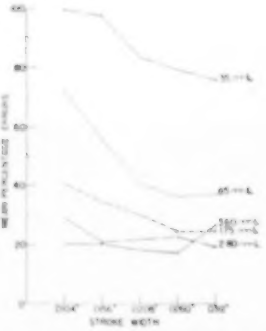
Figure 5. Mean error scores for reading four sizes of letters with four levels of transillumination and no background illumination.

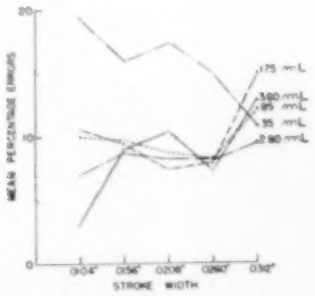
two widely accepted types, that designed by Berger and that in the AN Specification, reading errors are consistently lower for the proposed numeral design.

Arrangement of Markings

Arrangement of the markings with respect to each other on the control panel is especially important under transillumination. Even a cursory examination of a lighted panel shows that clustering of the markings tends to make a confusing and illegible display. Therefore, effective placement of the markings on the panel can enhance the legibility of even optimally designed letters and numerals. For example, one stroke-width spacing between letters within words, and one letter width spacing between words, have been found desirable in practice. Where legends can be separated on a panel, a maximum amount of space should be allowed between various legends so that the light flux shall be at a minimum from any part of the panel. As a general rule, legends are preferably arranged with the letters aligned side by side so that they read from left to right. Vertical lettering, therefore, is undesirable. Border lines, another form of marking, have been found to be unnecessary and confusing in most applications, but where they are used the line width of the border should not exceed the stroke-width of the nearby markings.

Attention-getting areas which include such legends as warning of limits that cannot be exceeded for safe operation need to be surrounded by some form of attracting border. Such warning panels have been found to require special design for use on indirectly illuminated consoles. This is a particularly illustrative example of a situation where a design satisfactory for ordinary daylighted or floodlighted panels is not satisfactory for indirectly lighted panels. For general floodlighting a wide border of contrasting color or a border of some special "barber-pole" design may be satisfactory. For indirect lighting, however, a preference survey of pilots completed in our laboratory has shown that markings consisting of a number of narrow angular lines surrounding the legend area produced adequate attention-getting power (Fig. 10). At the same time, such markings do not detract from the legibility of the legend nor do they





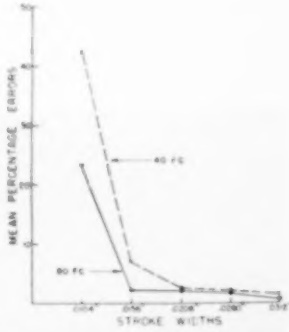


Figure 6. (Left) Mean percentage errors for reading capital letters .156″ high—five stroke widths, five transillumination levels. Exposure time 1/25 second for each group of three letters.

Figure 7. (Center) Mean percentage errors for reading capital letters .156″ high; five stroke widths; five transillumination levels. Exposure time 1/5 second for each group of three letters.

Figure 8. (Right) Mean percentage errors for reading capital letters .156″ high; two levels of floodlighting. Exposure time 7 milliseconds for each group of three letters.

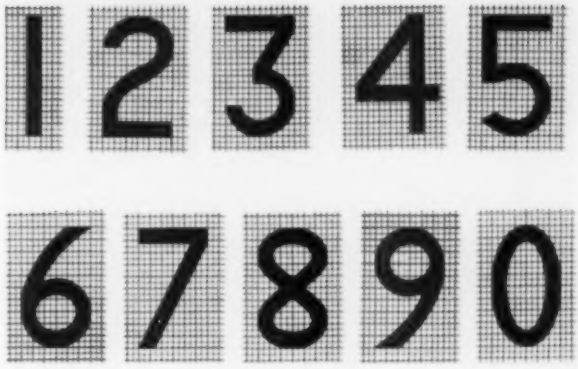


Figure 9. Proposed numeral design for high legibility.

add excessively to the total amount of flux which would be annoying or interfere with dark adaptation.

Another specialized situation is encountered with switches, knobs, and other forms of manual controls. One aspect of this is the lighting of the control itself which may be largely taken care of by the general low-level floodlighting previously mentioned. However, where the control is particularly important and its direction of orientation needs special emphasis, an indirectly lighted radial pointer design can be added. Further than this, the surrounding area needs some kind of reference marking. It has been found with one form, a continuously rotatable rheostat typical for volume control that an elaborate abstract design is not as satisfactory as a simple design with reduced area of illumination. Such a design might be a circumferential arc line with the positions of "off," "medium" or "bright" indicated by single words or by standard abbreviations (Fig. 11).

Effect of Floodlighting

Legibility tests were run to determine the effect on legibility of adding floodlighting to transillumination. It was found, as a result of a series of reading tests under various levels of red background floodlighting, that the addition of floodlighting reduces the contrast, but increases the marking brightness because the letters reflect the floodlighting. Increased comfort also results due to recognition of knob shapes, orientation within the cockpit etc. (Fig. 12). At low levels of floodlighting no great change in legibility occurs if legibility with only transillumination is already at the higher or lower extremes. For those letters at the threshold of legibility, the point of 50 per cent errors in reading, a definite decrease in legibility occurs when a low level of floodlighting is added. Higher levels of floodlighting in all cases increase legibility. When no transillumination is used, the floodlighting levels needed for legibility levels comparable to those with transillumination are higher than the highest used in these tests. This bears out the value of indirect lighting in reducing total light flux (Figs. 13 and 14).

A controlled experiment to measure the effect of floodlighting in conjunction with indirect lighting on the reading of a dial-type instrument was conducted.

A special dial reading device was utilized in the visual test enclosure previously described. This

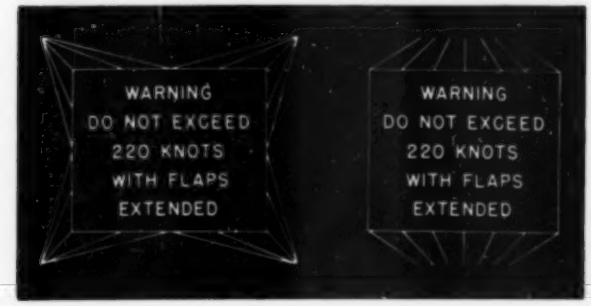


Figure 10. For indirect lighting, a preference survey of pilots indicated that markings consisting of a number of narrow angular lines surrounding the legend produced adequate attention-getting power.

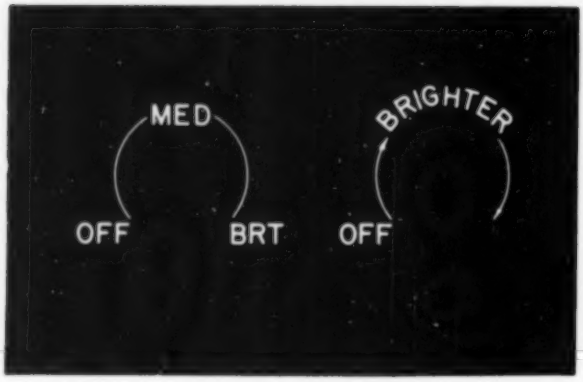


Figure 11. For indicated switches, knobs and other forms of manual controls, a simple design such as a circumferential arc line has proved satisfactory, with positions indicated by single words or standard abbreviations.

dial reader has four standard aircraft instrument dials mounted in a circular pattern. These are covered by a shutter so that only one dial is exposed at a time. The arrangement of the dial setting changes and shutter changes is such that eighty pre-determined dial readings are presented. Selected subjects were asked to read red transilluminated dial markings of different brightnesses with varying conditions of red floodlighting including no floodlighting. Opinions were tabulated on the desirability of the various conditions of brightness and illumination. Error scores were also tabulated. Reading performance in those test situations did not improve significantly above 40 microlamberts. However, the addition of floodlighting resulted in a more comfortable reading situation. A study was made in which 15 pilots expressed their preference for levels of console marking brightness (due to indirect red transillumination) and red floodlighting in an attack aircraft cockpit mockup. Each pilot was dark adapted for 15 minutes and was asked to select levels of marking brightness and floodlighting by operating rheostats. He was told to select the level which would give him the greatest visual comfort consistent with efficient operation in night flying. He was also asked to select the minimum levels at which duties could be performed. The results indicate that one level, .040 footcandle, of floodlighting to be used with a given marking brightness can be chosen to satisfy the lighting needs of nearly all aviators. In addition, provision could be made for voltage control by the pilot to bring the lighting level to maximum for exceptional circumstances.

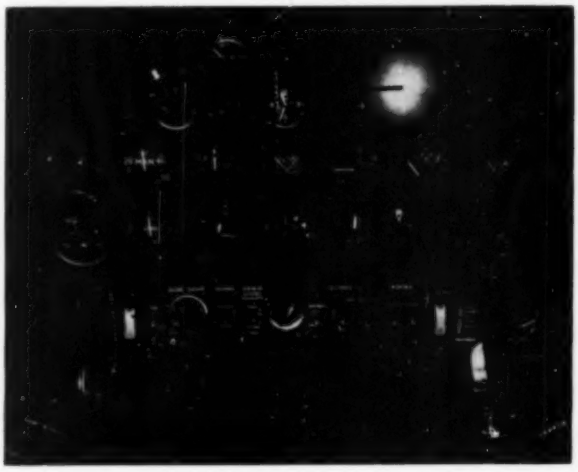


Figure 12. Studies on the effect on legibility of adding floodlighting to transillumination indicated red background floodlighting reduces the contrast but increases the marking brightness because the letters reflect the floodlighting.

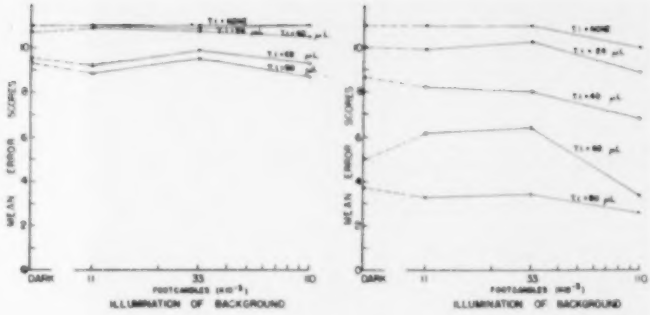


Figure 13. Mean error scores for reading .04 inch (at left) letters, and .06 inch letters (at right) for five levels of transillumination (T.I.) and four levels of background illumination.

Specialized Interior Lighting

Various specialized cockpit lighting problems must be solved in addition to the instrument and console lighting. The adequate distinction of warning lights in the cockpit is essential. These lights are used only for those situations and conditions which are sources of danger to the aircraft or its occupants. They should be of one color only: red, traditional for warning. For use during the day red is highly effective while in the red lighted cockpit the red warning light will nevertheless be distinguished easily by brightness difference. For additional attention-getting influence, relatively fast flashing of the lights is efficacious.

The development of the dark trace cathode-ray tube poses another cockpit lighting problem. The display is a magenta trace on a grayish white background. Unlike the usual cathode ray tube where the electrons fluoresce, this tube must be illuminated externally. The problem presented to our laboratory was to furnish light that would offer the greatest contrast with the least illumination to interfere with dark adaptation. Since the magenta trace is most reflective in the blue and red portions of the spectrum, it was necessary to filter the light so that the green portion is used to illuminate the tube's screen. In addition, the fixture developed for this purpose had to diffuse the light evenly over the surface to be viewed.

Exterior Lighting

Experiments and studies to improve the exterior lighting of aircraft with the view to lessening the visual difficulties attending night operations were begun by this laboratory in November 1944. Approaching the visual problems from the point of view of the pilot of an aircraft in flight, there were two considerations concerning the exterior lighting of another aircraft upon which emphasis was placed. These were: that the exterior lighting presentation must not result in confusion of the aircraft with something else; and the lighting must indicate instantly and clearly the direction of flight.

With these considerations as the guiding principles, extensive darkroom and flight experiments were conducted and results disclosed that the autokinetic illusion of confused movement, which results from looking at a single point of light in darkness, may be overcome if a row or rows of light are installed on the aircraft's exterior. Another device would consist of illumination of a part of

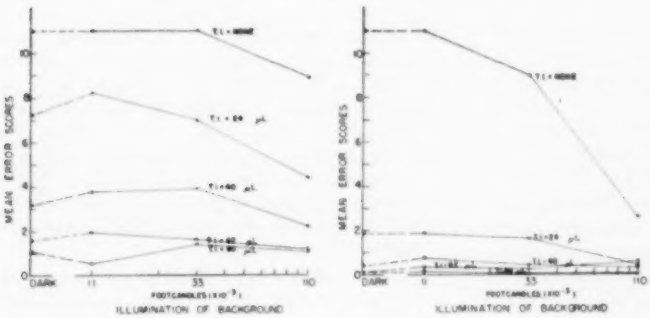


Figure 14. Mean error scores for reading .06 inch (at left) and .12 inch (at right) letters for five levels of transillumination and four levels of background illumination.

Figure 15. Delineation of the tail and wing tips by illuminating the trailing edges thereof provided a unique lighting configuration from every position observed.

the aircraft's surface. A further finding was that the combination of flashing navigation lights with steady top and bottom fuselage lights made it easier to judge the aircraft's distance and orientation in flight. It appeared that the steady white fuselage lights provided a central vertical reference axis which gave the aircraft thus lighted a unity that it otherwise lacked. For an observer to determine the attitude of the aircraft, it was found that placement of the lights on the wing tips, tail and fuselage provided the necessary information about the aircraft's three major axes. In addition, it was found that two properly spaced lights, preferably yellow and white, on the tail portion of the aircraft aided materially in both attitude determination and distance perception of an aircraft in the traffic pattern.

Recently, consideration has been given to increasing the rate of flash of the aircraft's navigational lights. The conference and lighting demonstration conducted by the Civil Aeronautics Administration in August 1950 showed that a step-up in the flash rate of the exterior lights from 40 flashes per minute to 60 or 80 flashes per minute may be desirable.

Studies conducted by this laboratory in recent weeks indicated that a step-up to 80 flashes per minute of the navigational lights would be desirable provided the on-off ratio of the lights was approximately 3:1. Further, it was considered desirable for the fuselage lights to be flashed with all the other navigational lights, so that the full benefit of the flashing presentation could be derived. Since the dark period is very short in this presentation tracking the aircraft would not be difficult.

Although studies conducted until the present have shown the directions in which improvements of aircraft exterior lighting can be expected, additional objective studies have now been initiated in our laboratory's stellarium. Through this experimental program data can be provided to indicate the precise ways in which configuration, color, brightness and flashing of lights lead to efficiency in detecting and recognizing the nature of an aircraft's movement.

Lighting for Formation Flying

Further investigations dealing with the special military problem of lighting aircraft to facilitate formation flying were undertaken. It became readily apparent that it was difficult to interpret distance, direction and relative speed for the purpose of spatial orientation from the visual information supplied by the conventional concentrated light sources. It appeared that these sources with their relatively high intensity at short distances tended to obscure the vague though more visually useful silhouette of the aircraft against the night sky. It, therefore, appeared that illumination of certain areas or contours rather than individual aircraft structural positions would do much toward providing a visual impression of the aircraft approximating that seen by day.

Various methods of providing these visual cues of aircraft form by illuminating characteristic areas and contours were tried. Brightness levels dim enough not to obscure, but rather accentuate the loom of the aircraft, were employed. Delineation of the tail and wing tips by illuminating the trailing edges of the rudder, elevator and of the wing tips provided a unique perceptual configuration from every position observed (Fig. 15). These installations consisted of plastic, translucent, structurally integrated strips internally illuminated by uniformly distributed light.

Another installation consisted of placement of a red filter covered light fixture (concentrated

source) at the trailing edge of the wing tips and wing roots. These lights served to delineate the wing. In this installation the concentrated light sources were later replaced with integrally mounted fixtures with extended colored plastic windows approximately five inches long by three-quarter inches wide. This installation served to elongate the concentrated sources and, therefore, aided the observing pilot to interpret the visual cues more directly in terms of the aircraft's major axes. These lights were called "linear formation lights."

The illumination of areas of the aircraft's surface was achieved by the method of floodlighting. Lighting fixtures, located within the aircraft behind windows, floodlit highly reflective white patterns on the tail and aft fuselage surfaces. Floodlighting utilizing both incandescent and ultraviolet lights was tried. In the case of the ultraviolet lighting the patterns were fluorescent painted instead of white.

Subsequent extensive flight evaluations by experienced Naval pilots showed a definite preference for the delineation method of utilizing the linear formation lights.

Carrier Landing Approach

A problem unique to carrier-based aircraft operations is the Landing Signal Officer's concern with identifying the attitude of an aircraft making a carrier landing approach at night. The Landing Signal Officer depends upon the interpretation of the aircraft's exterior lights for approach control. Naval aircraft are equipped with the usual exterior lights plus an approach light. The present approach light is a single lamp with a tricolor filter for presenting attitude information in the following manner: If, to the angle of view of the Landing Signal Officer stationed on the carrier deck, the light appears red, then the aircraft's nose is too low or the aircraft is approaching at too high a speed. Green indicates nose high attitude or slow speed, yellow, the correct attitude for approach. Another important indication furnished when the light is energized is that the wheels and hooks are in the locked-down position necessary for the landing. A new development has been the installation of three separate signal lights with carefully chosen color filters. These lights utilize information from a pitch gyro. A much higher level of brightness and a better distinctiveness of color have been observed with these lights as contrasted with the older approach light. More reliable information has also been obtained on the attitude of the aircraft.

Conclusion

These problems, so briefly reviewed, are typical of the work involved in developing design criteria for aircraft equipment to meet the visibility requirements of the human operator. The pilot's ability to control higher performance aircraft presents ever-new and more complicated problems. Our task is to gear our experimental laboratory studies to their solution.

DISCUSSION

W. C. Fisher*: The work of the Aeronautical Medical Equipment Laboratory has been of great assistance to the solution of many problems of lighting. Many of the recommendations of the Laboratory over the years are now commonly accepted, though at first were objected to by many persons. Many recommendations which were found to be most desirable from a human engineering viewpoint have had to be modified as a result of other factors. Thus when aeronautical design makes it impracticable to incorporate recommendations, it is often necessary for the "best" method to be modified to a greater or lesser degree. This does not lead us to the premise that physiological and psychological research should be discontinued, but only that we must employ the data this research provides with common sense and in the light of other criteria.

One of the most difficult lighting tasks is that of instrument lighting. This task requires that the designer meet requirements which are very difficult and frequently contradictory. The problem is further aggravated by the great variation in instrument design and dimensions which creates many problems. The following design criteria apply to instrument lighting:

(a) The lighting must be directed to prevent reflections in the cockpit enclosure and glare from direct radiation.

(b) The illumination must be relatively uniform over the instrument dial.

(c) The device must not interfere with mounting of the instrument or of adjacent instruments.

(d) The device must not restrict the visibility of the instrument dial from normal viewing positions.

(e) The device must be simple, sturdy and allow ready change of lamps in service.

(f) The device must not be a source of maintenance problems.

The present lighting fixtures reasonably meet the above requirements. They are at present the best answer to adequate instrument lighting of the flange mounted instrument until the advent of the internally lighted instrument.

For the new clamp-on type instrument, the fixture is of no use. The space available for light assemblies and the devices for clamping and mounting the instrument preclude its use. Other methods must be found to meet this problem. At present, no device has been finally decided upon. It appears that a miniature flood light mounted very close to the instrument offers the best possibility for a solution to the problem.

While the problems raised by Messrs. Brown and Alsher are of importance, the primary difficulty with exterior lighting of aircraft is not the flash rate or the configuration, but brightness and space. These two problems go hand-in-hand. As aircraft speeds increase, space in the outer area of the aircraft becomes more and more critical. Also the

*Department of Navy, Bureau of Aeronautics, Washington, D. C. The views expressed are those of the writer and are not intended to represent those of the Department of the Navy.

need for brightness many times greater than at present becomes apparent due to the much higher closing speeds. These twin problems do not appear to be solvable with known techniques and we may have to rely primarily upon electronic aids for cruise condition and lights only as a supplement and for landing and ground operations.

This problem of space is particularly acute in the case of the formation light problem. While the design of lighting delineated by Brown Alsher is undoubtedly desirable, space precludes its installation in many cases. In many aircraft, the trailing edge out to the tip is movable air foil which cannot accept any lighting. On other aircraft, the wing tips are covered with tip tanks.

MAURICE K. LAUFER*: Papers on aircraft lighting usually deal with subject matter that is controversial to a considerable degree. This paper is an exception since experimental work has been reported. Nevertheless, there are some statements that may be debatable.

One wonders why the addition of floodlighting to low-level trans illuminated panels decreases the legibility. All the other results of additive floodlighting might be explained in terms of improved contrast brightness ratios, that now popular field for illuminating engineers. Likewise, the use of the yellow and white tail light combination is puzzling. An airplane needs to pull away only a short distance from an observer for the yellow and white tail light flashes to become indistinguishable. Maybe it is important to differentiate between the two flashes only at short distances.

The authors' comments on flashing the fuselage lights with the navigation lights when the flashing rate is doubled immediately brings up another aspect of the multi-color problem. Possible confusion with the red wing tip light probably explains why the military has not used red for the second tail light color. If now, however, white fuselage lights were to be flashed with the tail light in particular, what color should the tail light be? Perhaps this will lead to the use of yellow only as the tail light color.

Digressing from the main subject of the paper, I'd like to raise a question on red lighted cockpits for our ultra-modern military aircraft. If the pilot flys, fights, bombs and locates enemy targets by means of radar, should we worry also about his seeing weakly illuminated targets. White lighted cockpits permit the use of all colors of the rainbow for identifying various categories of controls, safe and dangerous areas of indicating ranges, indicator lights, etc. Conversely, red lighting provides no color contrast, only brightness contrast.

I wish to emphasize one problem that requires serious consideration. Exterior lighting is fast approaching or rather has reached an impasse for the high operating speeds. The required intensity of these lights is astronomical and the space available for installation is infinitesimal if the streamlined aerodynamics of the airplane are not to be altered considerably. Perhaps all exterior lighting fixtures should be made retractable like many landing lights now employed. These could be extended near airports where speeds are reduced and traffic is heavy. Elsewhere the pilot could use radar to prevent the rather improbable collisions.

DAVID C. MILLER**: Mr. Brown and Mr. Alsher already know that in my opinion they have presented a wealth of information that will be of much immediate value to the aircraft lighting industry.

Frequent reference is made by the authors to instrument dial marking brightnesses ranging from 24 to 280 microlamberts of deep red illumination. In evaluating control and instrument panels being installed in aircraft, brightness values of red illumination to be measured generally range from .0002 to 1 ft-L; the major interest is in values below 0.1 ft-L.

The authors made no mention of equipment or techniques used in measuring these low levels of red illumination; I fully realize limitations on length would preclude any mention of this subject in a paper already including so much material.

There is no common agreement or understanding as to what type of meters should be used in measuring brightness of red (or any other color) illumination within the range indicated or as to how such meters should be calibrated.

The development and standardization of a procedure for measuring brightnesses below 1 ft-L must be resolved soon for several reasons:

(1) so that such work as Brown and Alsher have reported can be repeated or expanded by others.
(2) to make future studies on instrument lighting capable of comparison.
(3) to allow consistent and equitable appraisal by inspectors approving or rejecting instrument lighting equipment.

The problem will be a difficult one because, apparently, an arbitrary scale of brightness will have to be established. For a full explanation of factors involved, I refer you to a paper, "Vision at Low Brightness Levels — I," by A. H. Taylor (ILLUMINATING ENGINEERING, Vol. XXXVIII, No. 2, February 1943).

Basically, the problem is first to evaluate the Purkinje effect and then apply that information to meter design and calibration.

The Purkinje effect has been described in several ways. One way states "At some brightness level below 1 ft-L, probably about 0.1, the eyes begin to change in their relative appraisal of energy of different wavelengths, becoming relatively more sensitive to the blue and less sensitive to the red end of the spectrum."

Above one ft-L the eyes remain essentially constant in their efficiency of converting light energy of different colors into brightness impressions.

Hence, if a blue and a red transilluminated panel were adjusted to equal photometric brightness (or luminance) of 5 ft-L, and the energy from the lamps behind them reduced by 50 per cent, the resulting brightnesses would be 2½ ft-L for each. If the initial equivalent brightness level was 0.5 ft-L, and the energy were again reduced by 50 per cent, the blue panel would appear brighter than the red. With initial equivalent brightness of .05 ft-L, a 50 per cent reduction in energy would cause an even greater difference between resultant brightnesses.

Hence, in calibrating brightness scales for colored light below 1 to 0.1 ft-L, it is correctly assumed that brightness of the test surface decreases proportionately, with decrease of energy falling on it. This is called absolute calibration.

Below about 0.1 ft-L it is necessary to correct absolute calibration points for the Purkinje effect — i.e., for the progressive change in the eyes' efficiency in converting light energy to brightness sensations.

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**General Electric Co., Nela Park, Cleveland, Ohio.

What error would occur if the absolute calibration procedure were not modified to compensate for the Purkinje effect? Fig. 5 in the above mentioned paper by Taylor indicates that for very deep red illumination (cut off at 6100A) at a field brightness of .0002 ft-L, the error would approach 95 per cent; at 0.1 ft-L the error would be about 50 per cent.

The degree of possible error, I believe, indicates the necessity for standardizing a method of calibrating meters to be used in measuring the brightnesses of red illumination involved in instrument lighting.

LT. COL. WALTER F. GRETHER*: The paper by Brown and Alsher gives an excellent summary of our state of knowledge regarding a very important problem in the field of aviation, namely, "The Design of Aircraft Lighting to Meet Human Visual Requirements." The authors are highly qualified to report on this subject. Mr. Brown, in particular, has specialized in this area for many years, and has probably in recent years contributed more to the improvement of aviation lighting for efficiency of the aircraft crew than any other single individual. I have been much impressed with the intensely practical approach of Brown and Alsher, and with the soundness of their recommendations.

I have no critical comments to offer about the materials in this paper. Therefore, I will use my brief time instead to discuss some further problems in the field of instrument lighting, and touch briefly upon several recent studies carried out in the Psychology Branch of the USAF Aero Medical Laboratory.

Using ultra-violet flood, red flood, and red indirect lighting systems installed in our C-47 Airborne Laboratory, Major E. L. Cole has determined the luminance levels used by pilots in flight. The luminance values selected were in fair agreement for the three lighting systems. To be very brief, the following average luminance of the instrument markings were found to be employed: (1) About .01 footlamberts as the minimum for safe flight; (2) .02 to .03 footlamberts for normal use; and (3) .06 to .10 footlamberts for comfortable instrument reading without concern about outside vision. These values provide a helpful guide to designers of instrument lighting systems.

Using these luminance values, Captain L. R. Wilcox of our Laboratory has made measurements of pilots' dark adaptation in flight, using the red flood and red indirect lighting systems. Control measurements were made in a hangar in complete darkness. Even at the highest luminance level the loss in dark adaptation was hardly detectable, and certainly not sufficient to cause significant impairment of outside vision. This means, I believe, that our latest red lighting systems are successful in preserving dark adaptation. Any further improvement in outside vision, therefore, must come through other improvements, such as elimination of windshield and canopy reflections which mask the direct view of outside objects.

In addition to the red lighting systems already discussed, there appears to be a need for white instrument lighting of considerably higher brightness, probably 10-20 footlamberts. Such additional lighting is useful for thunderstorm flying and for simulated instrument flight using an orange hood and blue goggles. It may also be useful for daytime flight at altitude in certain aircraft, because of the instruments being in deep shadow.

The addition of high level white has given us three separate lighting systems in some of our new aircraft; red indirect, red flood, and white flood. This could be reduced to two systems if the white, operating at low voltage and hence low color temperature, could substitute for the red flood system. To explore this possibility Dr. K. T. Brown of our Laboratory has compared the effects on dark adaptation of red flood and low color temperature white light, using a simulated instrument panel. Two noteworthy findings came out of this study. First of all, the white light must produce a higher luminance than the red to give the same instrument legibility. With lights equated for legibility, there is a significant but small sacrifice in dark adaptation if low color temperature white is substituted for red. Therefore, in cockpits using indirect red as the primary system, we believe that a secondary white flood system, with a large range of voltage adjustment might make the red flood system unnecessary.

In conclusion, I wish to again compliment Brown and Alsher on their outstanding work in the field of aircraft lighting.

T. O. TWIST*: It is apparent from information contained in the paper by Messrs. Brown and Alsher that a tremendous amount of work has gone into the study of aircraft lighting problems. It is gratifying to see that aircraft lighting has been raised from the status of an "afterthought" and "quick decision" to one warranting scientific study for the many problems encountered in this field.

I was particularly interested in the references to instrument lighting and the systems employed, since much of my time has been devoted to the development of new instrument lighting systems for aircraft. I might add some information concerning the lighting evaluation carried out by the Air Force and Navy during the month of September 1949. The Navy's red lighting system evaluated in that test was the system of individual instrument lighting shields, and not the false-panel system, as implied. In the paper, mention was made of two systems of lighting, the Air Force ultraviolet, and the Navy system of individual fixtures. However, a third system was also evaluated. This was a system of floodlighting as proposed by the commercial airlines. It consisted of an installation of approximately 30 alternated red and white 3-candlepower lamps mounted beneath a glare shield above the instrument panel, and so arranged that no direct light was visible to the pilot or co-pilot. The white and red lamps were wired to separate rheostats so that the mixture of red and white light could be controlled. An additional feature of the system was that the backgrounds in the cockpit were painted with a low-gloss gray enamel. This system was found to be less desirable than either the ultraviolet or the individual fixture lighting since the final tabulation of results of the flight evaluation showed pilot preference as follows: Navy, Individual Fixture, red lighting, 62 per cent; Air Force, ultraviolet 27 per cent; commercial, 11 per cent.

In the paragraph titled "Instrument Lighting" the authors state that, "Although the lighting produced by these shields (individual instrument shields) is fairly uniform and causes a minimum of reflections from the canopy, nevertheless certain instruments show distinctly decreased levels of legibility."

In support of this, the lighting of the turn and bank

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*Naval Aircraft Lighting Unit, National Bureau of Standards, Washington, D. C.

instrument by the fixtures is cited. Decreased legibility of the turn and bank type of instrument does not result directly from using the individual fixture as contrasted, say, with the tailor made false panel or a system of flood lighting providing light which strikes the turn and bank indicator at near grazing incidence, but rather from the fact, as the authors state, that the instrument requires the incident light to be nearly perpendicular to the surface.

The authors are to be congratulated for providing the best information available regarding the size, legibility and spacing of markings as used for plastic lighting plates for aircraft control panels.

THEODORE H. PROJECTOR*: The authors have done an excellent job of investigating some of the important visual problems in Naval aviation lighting which their paper necessarily touches on only briefly. In a field where guesswork and prejudice were prevalent, they have done careful experimental work that has contributed to the development of greatly improved lighting equipment. Their work has also helped clear the way for the coordination of lighting equipment between the Navy and the Air Force.

The work done at AMEL to establish the superiority of red light for instrument and panel illumination in cockpits for the purpose of preserving dark adaptation confirms in practical situations the research work done in many other laboratories.

The quantitative studies on panel and marking brightnesses in cockpits have yielded extremely useful information on the optimum brightness levels for transilluminated markings and for supplemental floodlighting when dark adaptation must be maintained.

The problem of designing satisfactory navigation light systems for modern high speed aircraft and for other conventional and unconventional aircraft in our crowded skies has received considerable study by many laboratories including the National Bureau of Standards. It has become clear in recent years that navigation lights considered satisfactory ten years ago (and not too satisfactory then) are no longer adequate. Because of the increasing severity of the requirements and the limitations imposed on the electrical and aerodynamic characteristics of lighting equipment and on its size, shape, weight, and location, complete solutions to the problems are virtually impossible to attain. It has been recognized that tremendous increases in intensity of navigation lights are necessary as well as improvements in flashing rates and arrangements, in color, and in configuration. Although they have been proposed to improve identifiability, it is very doubtful that illuminated surfaces on aircraft can be obtained with brightnesses high enough to warrant their use in place of directly viewed sources.

Shortly after the CAA conference and lighting demonstration in August 1950, the National Bureau of Standards studied the problem of optimum flashing rate for navigation lights. The results of this study indicate that the flashing rates of wing tip lights should be increased from 40 to 60 or 80 flashes per second. It was found, however, that lights viewed near the visual threshold may not be flashed as rapidly for optimum conspicuity as may lights of high apparent intensity. The tests further suggest that for near threshold viewing too short an off period in the flashing cycle interferes with recognition of the light as a regularly flashing light. Since the low apparent intensity condition is the most critical one, I feel that the 3:1 on-off ratio recommended should be used only if the flashing rate is kept down nearer to 60 than 80 flashes per minute. It is to be hoped that the present program of test work at AMEL will provide more conclusive information on the relation between flashing rates, the composition of the flashing cycle, and the apparent intensity of the lights, as well as the other parameters. It might be well to investigate particularly the effect of atmospheric shimmer, especially important for near threshold viewing when considerable distance or relatively dense atmospheres are involved, on the identifiability of flashing lights.

R. A. RUDOE*: It is suggested that the thought in the third sentence under the subhead "Effect of Floodlighting" should stress the benefits of depth perception that is provided as a result of low level floodlighting.

This sense of depth perception along with the orientation gained from faint silhouettes under low floodlighting prepares one's eyes for reading indirect lighted panels and thus saves the time that the eyes require for focusing and starting the searching operations involved in reading.

The eyes are like any servo mechanism in that they need *time* for the coarse and fine adjustments as well as for correction of overcontrol by the eye muscles.

F. R. BROWN and DAVID ALSHER**: The authors are deeply appreciative of the constructive comments offered by those who have discussed this paper. Each comment adds to the collective body of information in this field. We should like to add further clarification on some of the points raised in the discussions.

Mr. Fisher emphasizes that inadequate brightness and size limitations are the primary current problems in exterior lighting, rather than flash rate or configuration. It is quite true that the required distance of visibility of exterior lights in higher performance aircraft is not being obtained because of limitations of source intensity. Lacking sufficient visibility distance, time for detection, recognition and response is significantly reduced. Therefore, in the absence of brighter sources, the available response time is being critically reduced. Increasing the attention-getting qualities of existing lights so as to shorten the time needed for their detection and recognition is the necessary recourse to overcome, in part, the deficiency imposed by reason of the dangerously close distances at which the lights can be seen. Flashing schemes for the lights are directed toward getting some increment of attention getting power within the limits of visibility imposed by the brightness. It is true, however, that a more significant improvement in exterior lighting would come from extending the visibility range through an increase of effective brightness. Improvements in flashing schemes and configuration, of course, would also be applicable to these brighter sources.

Mr. Laufer asks a pertinent question to which he also suggests the answer. The use of the yellow and white tail light combination is puzzling to him, because an airplane needs to pull away only a short distance for the two lights to become indistinguishable as to color. He adds, "maybe it is important to differentiate between the two flashes only at short distances." We point out that it is important, for close-in recognition at dangerously short distances, to have a color and configurational differentiation of two tail lights. In particular, in the traffic pattern, where it is very impor-

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*The Kilgore Manufacturing Co., Westerville, Ohio.
**Authors.

tant to recognize distance and direction of movement of the tail of another aircraft, the colored lights and their separation would have useful distinguishability at the critical distances. Further, to overcome the problem of tail and wing tip confusion, we would suggest that the white light flash with the other aircraft lights and that the amber light remain steady.

As to red illuminated cockpits, there are many considerations in favor of white lighting that are quite valid, as Mr. Laufer indicates. However, given present operational requirements, red light is the best. Since we have reason to believe that a high degree of pilot dark adaptation in certain kinds of aircraft operations and adequate legibility of complicated cockpit displays are both needed, it follows, as our investigations indicate, that red cockpit lighting is the best scheme to satisfy these requirements.

Mr. Miller discusses a very important and fundamental topic when he brings up the subject of photometry. The point is well taken that, if the Purkinje effect is ignored, the errors of measurement are significant. In our measurements we used a Macbeth Illuminometer calibrated especially for the low-level region of illumination, where most of our measurements were made. For this purpose, the Hartline attachment was used to reduce the size of the standard field to the size of the illuminated area being measured. This unit also includes means for using standard color filters to change the comparison field color to the color of the field being matched.

A New Laboratory for Lighting Design Data

Additional Discussion and Rebuttal on paper by W. M. Potter and A. H. Russell

(Published December 1951, ILLUMINATING ENGINEERING, pp. 619-627)

JOHN A. LOSH*: Increasing doubt is being cast upon the data of the lumen method, both derived and extrapolated. We know, as the authors point out, that we do not have the same conditions today as the original investigators had. Figure 6 of this paper points out the variation between experiment and lumen method calculations.

Figure 7 shows the same data as is shown in Figure 6, only it has been plotted as a function of domance instead of room index. A comparison between measurement and interflectance calculations is lacking.

The interflectance method would have predicted a higher k_u for the authors' Plan 1 over their Plan 2. This can be shown as follows:

The luminaire throws light only to the walls and floor. The efficiency of the luminaire is 1.00 for both plans. Then the coefficient of utilization is numerically equal to the interflectance according to the equation

$$k_u = f \cdot \varrho$$

f = interflectance

ϱ = efficiency

Because the luminaire throws light to the walls and floor, the interflectance is determined by the equation

$$f = f_1 F_1/F_D + f_3 F_3/F_D$$

where the subscripts 1 and 3 refer to the walls and floor respectively. F_D = lumens from luminaire = lumens from lamp in this experiment. f_3 is, for equal conditions, always greater than f_1. F_3/F_D is greater in Plan 1 than it is in Plan 2, therefore the interflectance, hence k_u is greater. Could the authors give a quantitive answer to this qualitative argument, based on their data, if only for a k_r of .80?

It is hoped that the insufficiency of interflectance data, as calculated by the SQQ committee, will not be a sufficient deterrent to a proper understanding of this method. Interflectances can be calculated for any ceiling height.

Referring again to figures 6 and 7, the difference in k_u between Plans 1 and 2 increased as the large room is approached. (RR $\rightarrow \infty$ or $k_r \rightarrow 0$.) As the room becomes very large, however, and for the distribution and other constants shown, the walls should have a decreasing effect on k_u. In the infinite room, the coefficients should be the same. This is not apparently the case in the authors' experiments, and I would like to ask them to obtain data down to a k_r of about .10 to check this point.

W. M. POTTER and ANSON RUSSELL*: We agree with Mr. Losh that utilization values for different luminaire locations should approach each other in rooms considerably larger than those included in Figures 6 and 7 and should become equal in an infinite room. Two curves such as those for Plan 1 and Plant 2 diverge and then converge at different rates depending upon the candlepower distribution and reflectance conditions.

We expect to explore larger rooms which will most likely suggest the convergence of the two curves in question.

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*Authors.

Ceiling Techniques

Shown on these pages are examples of store installations in which construction problems have been solved by various techniques of ceiling treatment.

Beam construction in this long narrow jewelry store dictated this rather unusual layout of a combination of recessed fluorescent two-lamp troffers equipped with glass bottoms, and 200-watt inside frosted lamps in silvered mirror symmetrical glass type reflectors equipped with louvers. This combination of fluorescent and incandescent lighting was recommended to produce color and sparkle on the merchandise. Illumination level is 90 footcandles average. *Photo courtesy of Duquesne Light Co., Pittsburgh.*

Incandescent lighting is effectively used in this ceiling pattern—highlighting the jewelry department of Halle Brothers, Cleveland. Eleven air diffuser units on 21′ by 20′ centers are equipped with 150-watt projector floodlamps. These units are adjustable and may be directed toward merchandise it is desirable to highlight. Fifty-three recessed 18″ Fresnel lens, opal-glass units, each equipped with one 75-watt bipost-base lamp, spaced 11 feet east and west and 13 feet north and south, supply the general lighting. Illumination levels are of the order of 41 footcandles on counter tops. *Photo courtesy General Electric Co., Lamp Dept., Cleveland.*

Ceiling technique combining louverall sections, standard fluorescent luminaires and recessed incandescent louvered reflectors, in a furniture store. The metal louverall ceiling has six 8-foot T-12 lamps mounted 24 inches on centers above each 24-inch section. The lamps are installed in a semi-concentrated type reflector. The standard fluorescent luminaires are ceiling mounted four-lamp units equipped with egg-crate louvers. Incandescent lighting is combined with the system, from recessed 200-watt lamps in silver mirror semi-concentrating glass reflectors with concentric louvers. Average level of illumination in service is 35 footcandles. *Photo courtesy of Duquesne Light Co., Pittsburgh.*

The problem of lighting a long narrow store has been met in this installation with a ceiling technique using louvered panels. At the Stetson Shoe Store in Pittsburgh, Pa., 48 louver sections 30" x 36" are hung below 63 40-watt lamps mounted on single strips, each with a reflector. Average level of illumination in service is 50 footcandles. *Photo courtesy of Duquesne Light Co., Pittsburgh.*

Some Ceiling Techniques for Stores

In this huge area—4000 square feet of the May Company store in Los Angeles—a louverall ceiling conceals a maze of unsightly pipes and rough beams. Despite the proximity of some of these pipes to the louver, very few shadows are noticed. In this ceiling, louvers are 3-inch square cells in 32-inch square sections, mounted 9 feet 4 inches, with a 20-inch cavity. Some 180 luminaires were required, using T-12 instant start slimline lamps with 425 ma ballasts. Illumination levels are 77 footcandles, with brightness values of 40 footlamberts at 30° and 85 footlamberts at 45°. *Photo courtesy Sylvania Electric Products Inc.*

A uniform ceiling pattern has been made possible in this Memphis store by allowing the modules of the louverall ceiling to control the size of the soffit built around the beams which run the length of the rear area. Recessed incandescent spotlights were added to give accent lighting and dramatic effect to the merchandise beneath. Square aluminum louver grid sections, 32", conceal fluorescent units suspended from the original ceiling. Two eight-foot units are mounted in tandem, using 75-watt slimline tubes. All wiring and air conditioning equipment is concealed above the louverall ceiling, which furnishes a maintained lighting level of approximately 50 footcandles. *Photo courtesy of Sylvania Electric Products Inc.*

Proposed Designs for Lighting Education in Home Economics Colleges

By KAYE A. LEIGHTON

HOME Economics Education has had a profound effect upon the development of the American standard of living. From its origin it has been an evolution from concentrated interest in foods and nutrition to an education which encompasses the whole complex procedure of Family Life. Today "The home is recognized as the most vital unit of society, basic to a sound social structure. Wherever there are homes there is need for education in the many aspects of home life."[1,2]

Colleges have expanded their courses in this subject from laboratory studies to practice teaching. Today's student knows not only what, but why, certain practices are recommended. This teaching trend has been particularly evidenced in the teaching of electrical service through the understandable usage of electrical appliances, such as ranges, refrigerators, washing machines, small appliances, etc. The value of these labor-saving, safe, efficient devices in homemaking practice is well accepted. Within recent years educators in this field have appealed to us to aid them in developing means and methods for teaching an understanding of good lighting practices.

As a result, time has been taken to gain an understanding of this field of education; to observe teaching methods; view such material properties and facilities as are now available for use, and also to review such endeavors as have been made to introduce the subject of artificial light and lighting as teachable material.

A reviewing of the available reference literature related to Home Economics Education reveals the fact that there is some very good material which would serve as a guide to meeting the general aims of the educators. These are listed under references. The volume "Management in Family Living," by Paulena Nickell and Jean Muir Dorsey,[3] deserves special mention for its complete and competent handling of this complex subject.

That the educator has had fully qualified reasons for complaints regarding past solutions offered in regard to lighting is evidenced by a viewing of the most recently constructed Home Management Houses and Apartments. Those responsible for the planning and designing of these practice-teaching units have given too little consideration to the aims of the educators. The lighting equipment installed was all too often of the commercial type, not residential. Little or no regard had been given to the relation of lighting application to the activities involved. As a result, there is no opportunity to teach the whys of good, recommended lighting practices which will have a carry-over into post-school life.

The purpose, therefore, of this paper is to present by the use of drawings, types of lighting equipment and installations which could be used for teaching. These units, if desired, might be used as laboratory equipment only. But realizing that good lighting, like all the other good contributions to life, must be lived with to be fully appreciated, it is our opinion that these units would serve best for practice teaching if incorporated within the Home Management House. The liberty has been taken, therefore, of presenting these lighting teaching units within room areas. Doing this shows how naturally and normally they fit into the whole development of home management and house planning.

I have termed this method of lighting application "Visual Planning." It will give organization to interiors without regimentation. The procedure is as follows:

First, list the visual requirements connected with the activities which you are planning for within the room area. Then proceed to organize on the floor plan the furnishings that are related to these activities. The next step is to develop the elevations, for only with elevation plans can interior designs be developed which will render service efficiently to the visual effort required for mental perception and the direction of bodily movements when performing any given activity. When this procedure is followed, lighting requirements will readily become evident and easy to solve. The range of light sources and methods of light control available today make possible a lighting solution for almost every seeing requirement. It is regret-

(*Continued on page* 90)

A paper presented at the National Technical Conference of the Illuminating Engineering Society, August 27-30, 1951, Washington, D. C. Author: Residential Lighting Specialist, Engineering Department, Lamp Division, General Electric Co., Cleveland, Ohio.

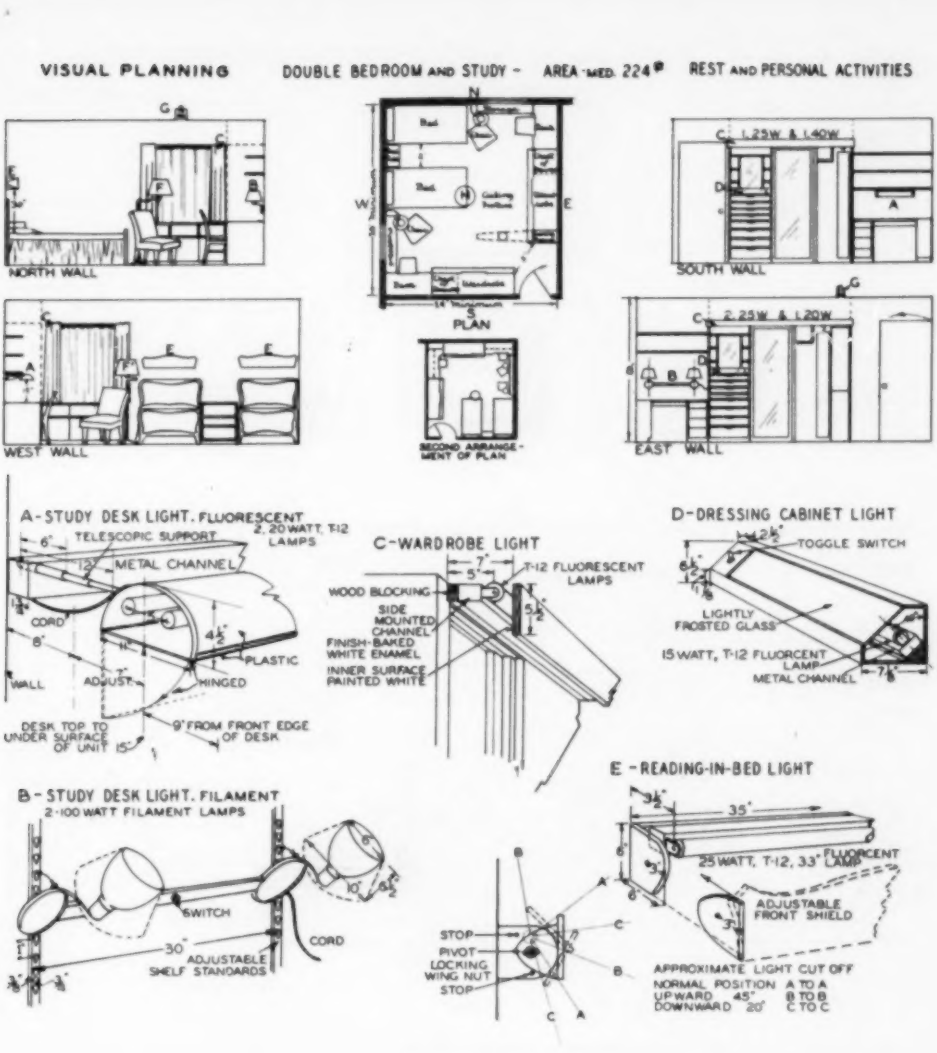

Figure 1.

Reading and writing, seated position. (A) Fluorescent wall unit, adjustment 7" horizontally. Movement of unit will demonstrate the interrelation between the angle of reflected light and the viewing angle of the user. (B) Filament wall unit, vertical movement for adjustment to eye level for eye protection.

Clothing selection (wardrobe storage)[7] and assembling of costume ensembles (full-length mirror). (C) Wardrobe light.

Facial make-up and hairdressing. (C) plus (D) Dressing cabinet light. Effect of two lighting distributions, downward and upward directions of light, plus combined distributions on complex surface form of face and head.

Reading, reclining position. (E) Bedlight, adjustable feature alters lighting distribution, 45° above and 20° below the horizontal.

Sewing, mending and manicuring. (F) Swing-arm lamp (50-150 watt) in extended position.

Casual reading, seated in upholstered chair. (F') Swing-arm lamp (50-150 watt) in closed position.

Pressing. (G) Recessed unit for 150-watt reflector lamp. Two distributions, spot or flood.

Maintenance, cleaning and packing. (H) Ceiling fixture, 20" diameter, 4 50-watt or 5 40-watt.

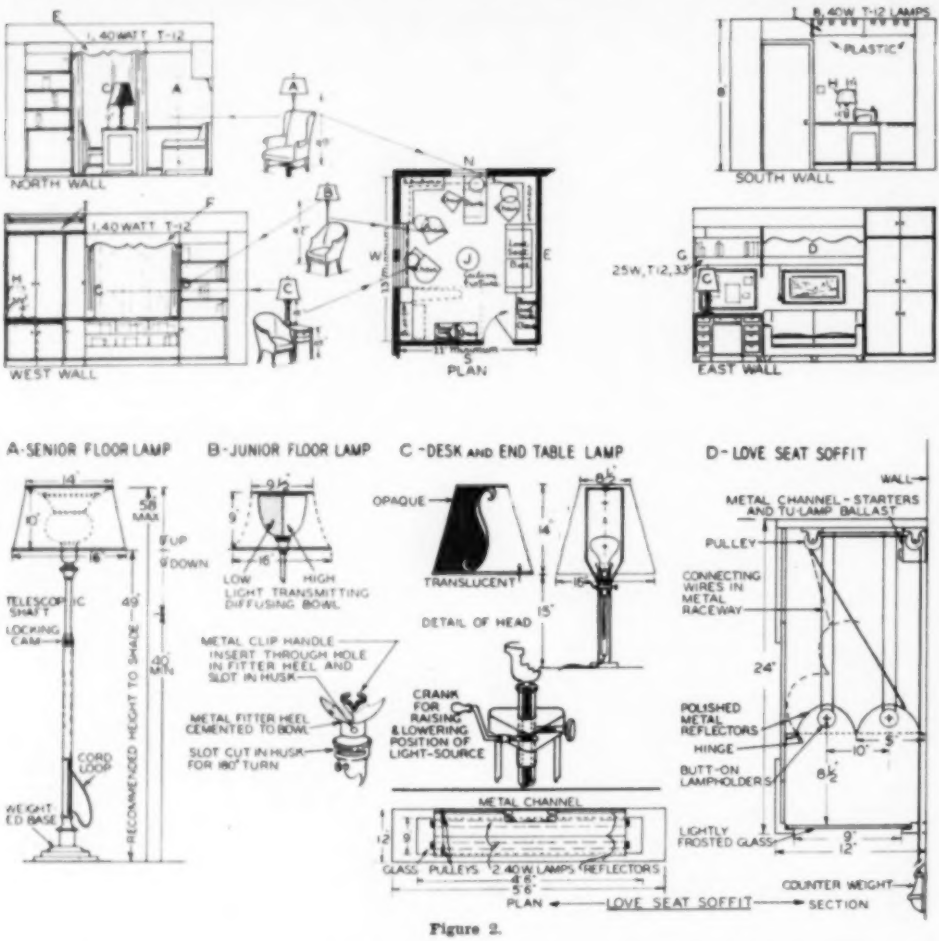

Figure 2.

Relaxed reading in a high back chair within limited space. (A) Senior floor lamp, height adjustment of 9" above or below the recommended height of 49". Effect upon lighting quantity and visual comfort of the other occupants of the room.

Reading, small-scale chair. (B) Junior floor lamp. Diffusing bowl, reversible for high to low brightness.

Reading and writing at desk. (C) Portable lamp, movable light source. Effect of source position within shade on lighting results. Shade one-half opaque and one-half translucent, visual comfort of unit in relation to background.

Reading, seated in chair, 25" high end table. (C) Portable lamp, movable light source. Effect of source position within shade on lighting results. Shade translucent fabric; 16" bottom; 8" top; 14" depth. Effect of brightness distribution of shade.

Reading, seated or reclining. Love seat bed. (D) Soffit, built-in fluorescent unit. Utilizes limited space. Reflectors of polished metal are removable by pulley mechanism. Demonstrates effect of directional control.

Restoration of daylight effect. (E) Fluorescent valance unit.

Restoration of daylight effect, plus magazine selection. (F) Fluorescent valance unit.

Bulletin Board notices. (G) Fluorescent lamp back of 4" wood shield.

Machine sewing. (H) C.L.M. wall lamp (50-150 watts). Recommended positioning.

Fine, detailed work. (I) Ceiling installation providing high levels of illumination.

Card playing; general activity, such as cleaning, etc. (J) Ceiling fixture, 19" diameter; 4 60-watt or 5 50-watt

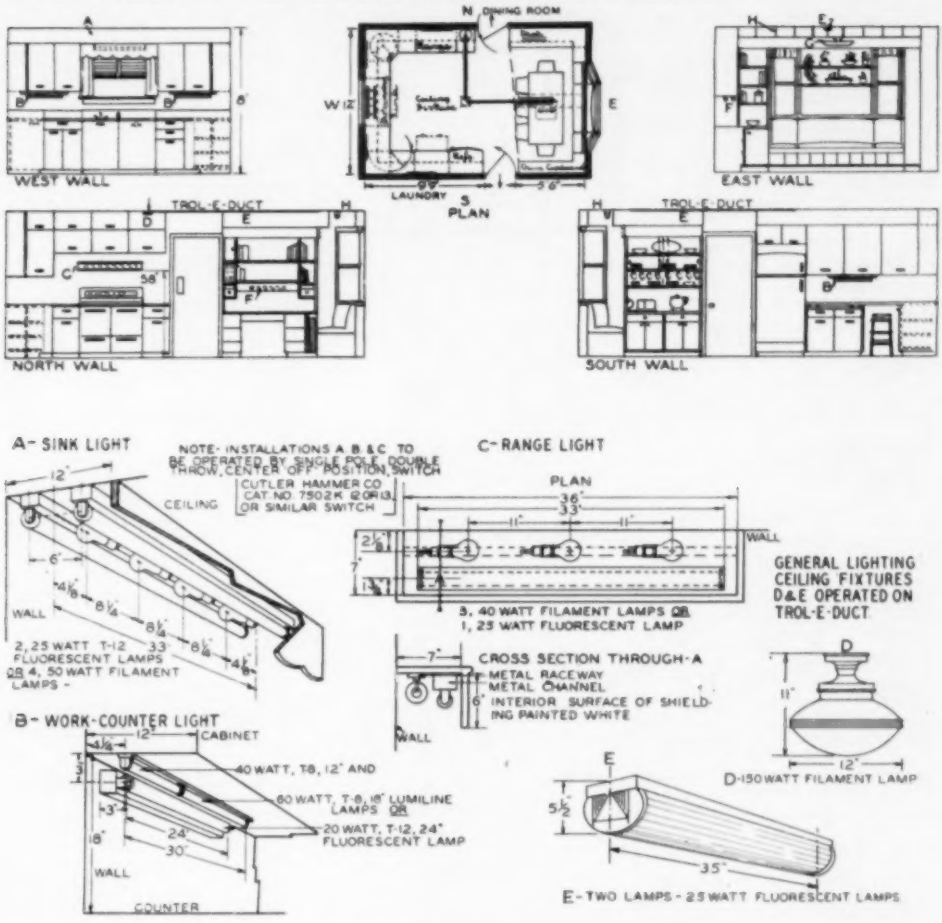
VISUAL PLANNING - KITCHEN AND DINING ALCOVE FOR PRACTICE TEACHING
WEST WALL
PLAN
EAST WALL
NORTH WALL
SOUTH WALL
TROL-E-DUCT
A- SINK LIGHT
NOTE- INSTALLATIONS A B & C TO BE OPERATED BY SINGLE POLE DOUBLE THROW, CENTER OFF POSITION, SWITCH
CUTLER HAMMER CO CAT. NO. 7502K 20 OR 13 OR SIMILAR SWITCH
CEILING
WALL
2, 25 WATT T-12 FLUORESCENT LAMPS OR 4, 50 WATT FILAMENT LAMPS -
B- WORK-COUNTER LIGHT
CABINET
40 WATT, T8, 12" AND 60 WATT, T-8, 18" LUMILINE LAMPS OR 20 WATT, T-12, 24" FLUORESCENT LAMP
COUNTER
C- RANGE LIGHT
PLAN
3, 40 WATT FILAMENT LAMPS OR 1, 25 WATT FLUORESCENT LAMP
CROSS SECTION THROUGH-A
METAL RACEWAY
METAL CHANNEL
INTERIOR SURFACE OF SHIELDING PAINTED WHITE
GENERAL LIGHTING CEILING FIXTURES D&E OPERATED ON TROL-E-DUCT
D-150 WATT FILAMENT LAMP
E- TWO LAMPS - 25 WATT FLUORESCENT LAMPS

Figure 3.

This unit of kitchen space is designed so that with approximately equal lumen quantities it may be lighted by either filament or fluorescent lamps. Metered separately from the rest of the house, tests could be run on initial cost versus operating cost, lamp life, maintenance, personal preference, etc. The use of Trol-E-Duct, mortised into the ceiling, makes it possible to alternate even the ceiling fixtures.

Within the dining alcove two levels of lighting are provided. (G) Square ceiling fixture (19"), using 4 60-watt filament lamps, and (H) recessed fluorescent lighting. These systems both offer a decided change from the utilitarian lighting of the kitchen area.

The planning desk. (F) Uses a built-in study desk, fluorescent lamp installation, 2 20-watt lamps, positioning the same as for (A) in Figure 1.

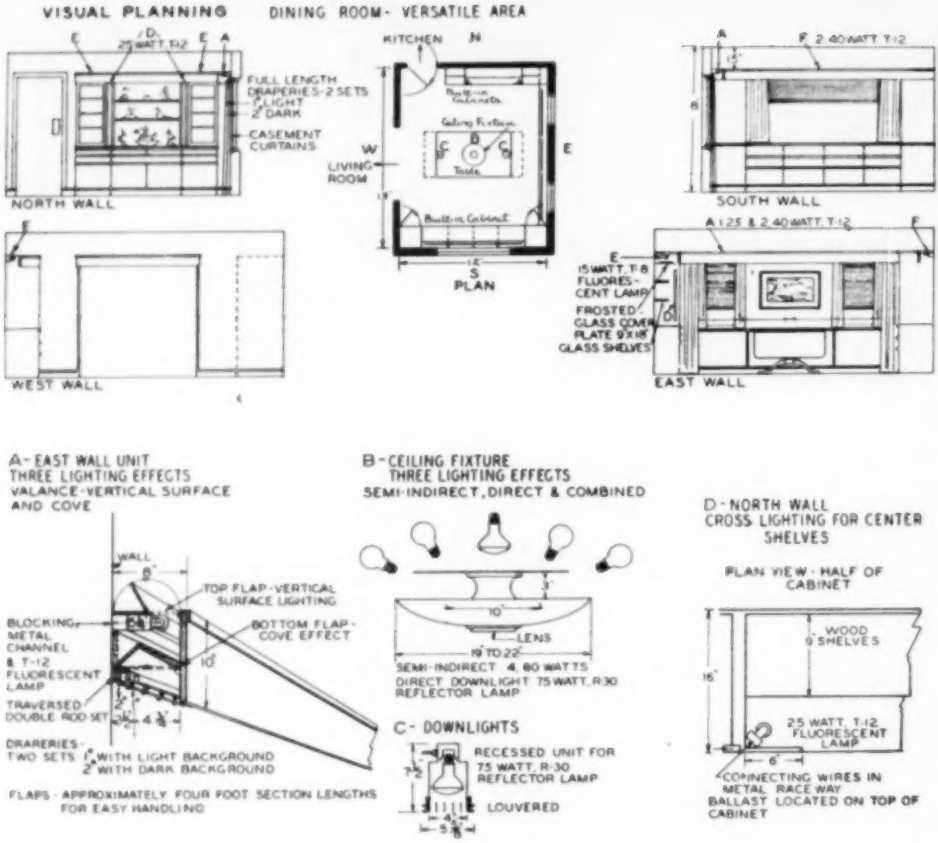

Figure 4.

The adjustable teaching unit in this room is located on the east wall. **(A)** Three lighting effects, individually controlled.—1. Valance, open top and bottom, lighting both ceiling and wall surface; 2. Vertical surface, wall lighting, top closed, and 3. Cove effect, ceiling lighting only, bottom of unit closed. By the use of two sets of draperies it is possible to demonstrate the effect of light absorption by dark materials versus light reflecting draperies, and the resulting effect upon the room and the individual.

The north wall cabinet, which contains planned storage for silver, table linen and extra leaves, as well as dishes and serving dishes, also incorporates two lighting applications.—1. Down lighting made possible by the use of glass shelves, and 2. side cross-lighting required for center wooden shelves. **(D)** and **(E)**.

As the plan illustrates, the south wall has two closets between which is a built-in cabinet, 34" high, for the storage of electrical appliances, toasters, waffle iron, sandwich maker, etc. When the top is used for serving buffet suppers, it may be lighted by the fluorescent, concealed lamp in back of the valance shield. **(F)**.

This room is so designed that it may be converted into an extension of the living room, made into a study or used as a music room or children's play space when desired. Convenience outlets make provision for the addition of portable lamps.

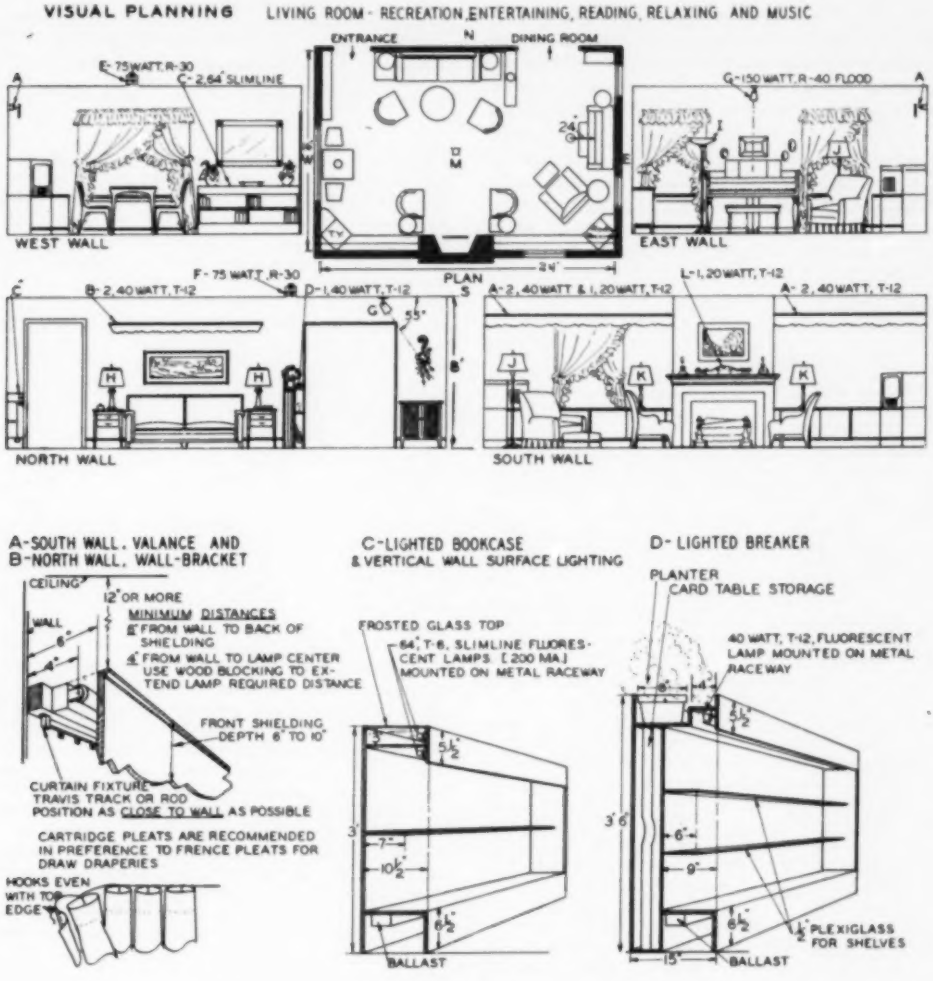

Figure 5.

This living room has been designed as an example of the fact that most living rooms are just a comfortable expression of family living, not examples of high decoration. Modern lighting practices can be applied without disrupting this feeling, rather they add to the functional usage of the room, expanding its service to family living.

A variety of lighting combinations may be used, all dependent upon the effect desired for the activity taking place at any particular time. Such a room will provide variable, delightful livability for its members. It really offers competition to outside-the-home interests and decidedly invites relaxed companionship for family members and friends.

Only one room arrangement is here presented. At least three others could be made with the furnishings illustrated, as all features, including the lighted bookcase and breaker, are movable.

able that this form of electrical service has been so long used incorrectly and with such great economic and human energy waste. The lighting elements presented make possible the demonstration of lighting principles as active living applications.

All equipment design conforms to recommended quantities and qualities of lighting as set forth by I.E.S. Recommended Practices for Residential Lighting. (See Reference Nos. 17-20.) The use of this method as a basis for teaching would enable the students to prove to themselves why certain lighting practices have been found to be good and are, therefore, recommended.

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DISCUSSION

ELIZABETH O'KELLY*: In my opinion, the principles set forth in this article definitely meet a vital need for aesthetic and artistic satisfaction within the furnishings of a home management house, but most important of all meet the requirements of eyesight protective lighting. This is a function universally neglected throughout the homes of today and particularly in the home management houses and college dormitories where visual tasks are being performed constantly under inadequate lighting conditions, thus causing much eyestrain and defective vision. Therefore, our lighting educational task must be a constant presentation of written and illustrated information, such as Miss Leighton has done in this article, until college and other educational authorities finally "see the light" and accept it as a required part of the courses taught in Home Economics Education.

The facts presented by Miss Leighton have a natural application to the needs of students of all ages. All grade, high school, and college authorities need to accept these truths and practice them not only in the classroom but in the home living areas. Never has there been so great a need for these basic facts to become a required part of teaching home management: yet those in charge of planning such courses of study have failed to recognize the importance of teaching this phase of health and family living.

As to the fact that lighting has been a neglected portion of home economics teaching, I speak from experience. While I was a home management teacher and supervisor of three residences on the campus of one of the most outstanding of our southern colleges, I tried desperately to gain consent of the college authorities to install adequate lighting in these houses. The budget committee would not hear of doing so and would not even consent to purchase a few portable lamps for the study and sewing areas, thus forcing the students to continue studying by overhead ceiling fixtures suitable only for general lighting. I resorted to the teaching of some lighting principles by demonstration with the light meter and a personally owned I.E.S. study lamp in my classroom lectures, but could not give laboratory practice within the management houses for such study of lighting.

I say again, therefore, that this educational task is a great one that we must continuously promote until educational authorities take some action upon it.

MARION WALKER**: In the July 1951 issue of ILLUMINATING ENGINEERING the Committee on Residence Lighting of the Illuminating Engineering Society reported on an approach to planning for home lighting by definition of areas to be lighted, with respect to furniture and furniture groupings and in relation to the eyes of the user. The idea has been further developed in Miss Leighton's report with excellent suggestions for the teaching of lighting in home management houses in home economics schools and colleges. "Visual Planning" as described by Miss Leighton would precede, in this case, an understanding of the objectives of the home management houses and needs of the students for home

*Regional Home Economist, Rural Electrification, Washington, D. C.
**School of Home Economics, University of Georgia.

management living. Her report indicates an awareness of many of these needs and objectives.

Objectives in the various schools differ. However, usually a small group of students live in the houses for a period of from three weeks to a semester, and each student at some time during this period is responsible for all of the various activities carried on in the home. Scientific principles learned in the class room are applied and evaluated in terms of everyday living, and practice is gained in homemaking skills learned in the laboratory. It is important, therefore, that facilities in the house permit application of principles the student has learned; otherwise, they may be forgotten or discarded as unimportant. Unfortunately, there is a lack of engineering knowledge in the planning of lighting in home management houses. Emphasis is usually placed on the creation of attractive looking rooms, with little thought of activities for which the lighting is to be used. Colleges too often overlook the opportunity for further teaching of lighting and housing through living in functionally-planned home management houses which incorporate the best practices in these areas.

Home management houses are used as laboratories for teaching lighting in many schools. It is felt that in this way students are likely to be more alert to the type and quality of lighting used when they come to live in the houses and will have a better background for evaluation of it. Miss Leighton's suggestions for more flexible lighting offer many possibilities for more effective teaching through use of the houses as laboratories in home lighting courses.

Specialists in the field of family housing and home management would possibly disagree as to the feasibility of the large bedrooms and two full-length mirrors in each of the bedrooms from the standpoint of economy. Some authorities suggest that the beds be two or three feet from the wall to facilitate the changing of linens, and the American Health Association has set a distance of three feet between beds as the minimum recommended to help prevent the spread of infectious diseases. Little research has been done in the field of housing, however, and few principles established. Miss Leighton shows an understanding of many of the problems, and so far as the writer knows she has presented the first complete lighting recommendations for the teaching of lighting in home management houses. Her report is timely and presents a new approach to planning and the teaching of lighting in schools of home economics.

EDITH L. BUCHHOLTZ:* Miss Leighton has done an excellent job of designing laboratory equipment for teaching home lighting to Home Economics classes. One cannot study these drawings without getting the urge to develop them further, and without realizing the potentialities for their use. First of all, I would like to see designs of this type extended to lighting applications in the two missing rooms — the utility or laundry room and the bathroom. One specific design that I would like to see developed further is the love-seat lighting in the multi-purpose room. There is a pulley system designed to raise and lower the reflector, thus suggesting to the student the advantages of using such equipment above the lamps. If this were designed so that you could show the student not only the effect with and without a specular reflector, but also show the effect of a good reflecting surface such as you have around the light source in the kitchen sink valance and the noticeable effect if such a surface is of low reflectance. The device, of course, might be a little more complicated to build, but it seems to me that the added teaching points would make it worthwhile.

Referring to the kitchen installation, I have a question about the light sources. In view of the possibilities of eventual widespread use of de luxe fluorescent lamps in the home, would you have recommended two 40-watt lamps over the sink, had the span been long enough?

In my opinion an indication of white or light-colored reflecting surfaces should be included in the drawings where they are definitely needed for satisfactory lighting results, such as the areas around the light source in the sink valance, bed lighting valance and dressing table units.

While excellent desk lighting units have been provided, in the bedroom-study room the lamps designated as furnishing lighting for hand sewing, mending and manicuring are not an example of the best units recommended for these tasks. I realize that excellent lighting for fine work is available in the committee room but, of course, only one girl at a time could use this area.

As a whole, I believe these devices would prove very helpful to any instructor teaching a unit on residential lighting and may even encourage some schools to plan more extensive educational work in this field. However, having had a taste of Home Economics, both as a student and on the teaching staff of a large college, I cannot entirely agree with the statement that these devices "would serve best for practice teaching if incorporated within the Home Management House." My reasons are two-fold: (1) Home Economics students generally do not enter the home management houses until their senior year. All the basic laboratory background study on food preparation, clothing construction, textiles, housing and household equipment are learned during the Freshman, Sophomore and Junior years of college, so that work in the home management house is a matter of applying facts already learned. I feel that a study of lighting equipment should also be included as laboratory study during the earlier years of college — not delayed until the senior year. (2) Basically, the Home Management houses are designed to be homes, not laboratories, and for the most part they are operated on a specific income level. Thus, it seems *more* logical to me, to install a single adequate lighting system in each house representative of its particular economic level, than to install a series of experimental devices.

Thus, in the Home Management house, the college senior would not be confronted with new fundamentals or with lighting laboratory conditions. With all of this basic study accomplished as part of one or more courses during the first three years, the home economics student in her senior year would be well prepared to intelligently experience and appreciate living with good lighting, as it might normally vary house-to-house according to economic level.

KAYE A. LEIGHTON*: The author appreciates the time and effort given by the discussors in comment upon this paper. It seems the best procedure is to comment on each discussion separately and in turn.

Discussion No. 1. Miss Elizabeth O'Kelley, whose present position is as a Regional Home Economist for the U. S. Department of Agriculture, Rural Electrification, Washington, D. C., has an excellent educational background and a long period of wide experience in both academic and practicing work in the field of Home Economics. This wide experience, which encompasses both an educational and a

*Westinghouse Electric Corp., Lamp Div., Bloomfield, N. J.

*Author.

commercial knowledge over a large territorial range, makes her comment of value. It certainly constitutes a vote of confidence for the continuation of such endeavors in this field of lighting education and application.

Discussion No. 2. Mrs. Marion Walker is at present Assistant Professor of Household Equipment, School of Home Economics, University of Georgia. She has given tangible evidence of her interest in and desire to forward the teaching and practical application of good lighting principles in Home Economics Education. In addition to this she has a fine background working knowledge of the work now being conducted in housing research and development by various groups. She could, therefore, evaluate the content of the paper in regard to its contribution to, and coordination with, this educational approach to the improving of current housing practices for student teaching and post-school application. For these reasons her comments are of great value and much appreciated.

In Paragraph 4 Mrs. Walker cites the two features which she feels might receive criticism. In both cases planning could be altered to adjust. The reason for providing two full-length mirrors was to establish a consciousness of the need for equal dressing facilities for members of a family when an overlapping of time is a factor in home management.

As to the second point, distance between beds, the room size selected was that given by Ramsey & Sleeper, Architectural Graphic Standards, for University Housing Type No. 2, Double Study and Bedroom; Areas—Large, 250 sq. ft.; Medium, 225 sq. ft.; Small, 200 sq. ft. The conservative choice of medium size was made. Aside from this space limitation, I am in perfect agreement with the points cited. It is evident that more square footage would be required to execute the plan. This is nevertheless a good thing to know in advance, as too many houses are composed merely of allotted space areas, requirement development never being taken into consideration until the time of occupancy. As a result of this, both room arrangement and necessary storage facilities are sacrificed.

Discussion No. 3. Miss O'Kelley and Mrs. Walker have grasped the full intent of the paper, and they have clearly expressed their appraisal of the need for this paper. Miss Buchholtz overlooks the broad concept of "Visual Planning" and the great impact that we feel it is going to have on both the teaching of lighting and the design of all homes. Today we are establishing new patterns for family life, and Visual Planning will become of extreme significance in this development.

The nature of Miss Buchholtz' comments indicates that she was formerly a student and later a member of the teaching staff of a Home Economics College. It should be noted though that her overall comments are in direct contradiction to those expressed by the other two highly-qualified discussors. From years of working with students and the public we know the value of having demonstrable lighting elements in their natural environments. We cannot, therefore, accept the proposition of a single fixed lighting system for the home management house. This completely defeats one of the fundamental purposes of the house, that is, the application of scientific principles learned in the classroom and evaluated in terms of everyday living.

The basic principles of lighting for living are essentially the same for all income levels. Therefore, there seems to be no valid reason for thinking of these as being subject to change with the size or style of a house or the income level of the family.

The Papers Committee of the Society has established fixed limitations on the volume content of convention papers. Complying with these specifications necessitates a close editing of content. Many operational aspects of this and related materials could not, therefore, be included. We consider this paper merely a beginning in the educational field.

Did You Know . . .

that over 96 per cent of Sweden's generated eighteen and a half billion annual kilowatt hours comes from water power? Sweden is perhaps the only country today with excess electricity, and plans are being considered to transfer power by submarine cable to Denmark where local fuels or hydro-power are almost wholly lacking. Roughly half the generating and distributing companies are privately owned, the remainder by the State or Municipal authorities. Distribution system standardized is three phase a-c 380/220 volts.

Much of Norway's potential hydroelectric power is undeveloped for lack of capital, hence the use of household and commercial electricity, such as for heating and lighting, is considerably restricted. (Information submitted by S. G. Hibben, I.E.S. President)

Dust Box and Field Trial Tests of De-Staticizers as Used on Polystyrene Luminaire Panels

By GEORGE P. WAKEFIELD

POLYSTYRENE plastic is used to a considerable extent in present day fluorescent luminaires for luminous side panels or luminous louvers. Its primary function is one of transmitting a small degree of flux to the eye, thereby producing a luminous side panel or louver. For side panels this luminous effect is of primary importance in imparting a luminaire side brightness comparable to the normal viewing background. For louvers a characteristic of luminosity or lightness is obtained which is advantageous.

All these inherent qualities of styrene are of little practical use if the plastic, by virtue of its ability to attract dust and lint with its electrostatic charge, is no properly de-staticized. After discovering the importance of a charge inhibitor from installations in the field it was apparent that if styrene was to continue assisting luminaire designers its efficiency should be studied and remedies observed. This report attempts to analyze the problems of styrene in relation to luminaires. It is not a complete report as de-staticizers go on ad infinitum.

This paper has been reviewed and approved by the I.E.S. Sub-Committee on Depreciation in Maintenance of Office Lighting Systems.
Author: The F. W. Wakefield Co., Vermilion, Ohio.

Method of Dust Box Test

In order to study styrene panels on luminaires a dust box 50 inches long by 16 inches high by 16 inches wide was built. In it was suspended a lighted luminaire. The dust medium consisted of carbon black powder and wool vacuum cleaner sweepings. To activate the dust a jet of air was forced along the bottom surface of the box. After each test the dust was allowed five minutes to be attracted to the styrene. The amount of lint visible on the inner side of the panel determined the rating of the de-staticizer. The inner side of the panel was used in these tests because it provided a protected surface free from gravity falling dust particles which would not be an indication of static attraction.

In the dust box test, to first test the operation of the box, a water washed piece of styrene was in-

TABLE I.—Dust Box Tests.

Description of De-Staticizer	Supplier	As Coated Score*	Dry Rag Wipe Charge**	Dry Rag Wipe Score*	Wet and Dry Rag Wipe Charge**	Wet and Dry Rag Wipe Score*
None		Dirty	Heavy	Dirty	Heavy	Dirty
"Vel" mixed with water	Colgate	Clean	Slight	Dirty	Heavy	Dirty
"Merix" anti-static compound #79	Merix Chemical Co. Chicago 11, Ill.	Clean	None	Clean	None	Clean
"Anstac" P. S. lot #858	Chem. Dev. Corp. Danvers, Mass.	Clean	Slight	Clean	Heavy	Dirty
"D-Stat B"	Roxbury Chem. Works Centerdale, R. I.	Clean	None	Clean	Heavy	Dirty
"Wilco" Plastic Cleaner #5	Wilco Company Los Angeles, Calif.	Clean	Heavy	Dirty	Heavy	Dirty
Tetra Sodium Pyrophosphate	E. I. duPont Crasselli Division	Clean	Heavy	Dirty	Heavy	Dirty
Johnson's "Glo-Coat"	Johnson Company Racine, Wisconsin	Clean	None	Clean	Heavy	Dirty
Plastic panels with standard solution as supplied by Manufacturer A		Clean	Heavy	Dirty	Heavy	Dirty
Plastic panels with standard solution as supplied by Manufacturer B		Clean	Heavy	Dirty	Heavy	Dirty
Mac's speed glaze (car polish 4% silicones)	Mac's Super Glaze Co. Los Angeles, Calif.	Clean	Slight	Dirty	Heavy	Dirty
"Glim"	B. T. Babbitt New York, New York	Dirty	Heavy	Dirty	Heavy	Dirty
Sulphonated detergent plus glycerine and water		Clean	Slight	Dirty	Heavy	Dirty

*Rating according to visible carbon black, dust and lint.
**Rating according to visible lint (wool).

TABLE II.—Plastic (Styrene) Side Panels Field Tested in an Office.

Description of De-Staticizer	Supplier	Mixture	Score*
"Val" mixed with water	Colgate	2 tbl.spoon/gal. water	Clean Clean Clean
"Merix" anti-static compound #79	Merix Chemical Co. Chicago 11, Ill.	As supplied	Clean Clean Clean
"Anstac" P. S. lot #658	Chem. Dev. Corp. Danvers, Mass.	As supplied (inflammable)	Clean Clean Clean
"D-Stat B"	Roxbury Chem. Works Centerdale 11, R. I.	As supplied	Clean Clean Clean
"Wilco" Plastic Cleaner #5	Wilco Company Los Angeles, Calif.	As supplied	Clean Clean Clean
Tetra Sodium Pyrophosphate	E. I. duPont Grasselli Division	4 tbl.spoon/gal. water	Clean Dirty Dirty
Johnson's "Glo-Coat"	Johnson Company Racine, Wisconsin	As supplied	Clean Clean Clean
Plastic panels with standard solution as supplied by Manufacturer A		As supplied	Clean Clean Clean
Plastic panels with standard solution as supplied by Manufacturer B			Dirty Dirty Dirty
Mac's speed glaze (car polish with 4% silicones)	Mac's Super Glaze Co. Los Angeles, Calif.		Clean Clean Clean
"Glim"	B. T. Babbitt New York, New York	1% solution	Clean Clean Clean

*Rating according to visible dirt collection.

serted in the luminaire and the mentioned cycle run. This piece definitely came out "dirty." See the first item in Table I, identified as "None."

In order to measure some degree of permanence, the same piece of styrene was briskly rubbed ten strokes on each side with a clean dry rag. This treatment charged the plastic while providing an accelerated in-the-field maintenance test such as would be provided by wiping the side panels with a dry rag. Results are shown in the two columns under "Dry Rag Wipe." The score was "Dirty."

To intensify the permanence test further, a clean wet rag was rubbed ten times over each side of the panel. This was repeated with a clean dry rag and the test cycle again repeated. Results are shown under "Wet & Dry Rag Wipe." This test was aimed at duplicating water washing of panels in the field and is construed to indicate the de-staticizer's resistance to water.

Field Trials

In order to prove the results of the test-box observations the same de-staticizers were used on similar styrene panels and luminaires in a large factory-office building. After four weeks exposure in a dust laden interior (renovation of the office interior was proceeding) two observers judged the side panels. Results are shown in Table II under score.

Conclusions

Field trials show that untreated or improperly de-staticized styrene side panels attract so much dirt as to make the plastic impractical. Improperly applied de-staticizers can provide as impractical a styrene panels as styrene without a de-staticizer due to the unevenness of the attracted dirt.

De-staticizers vary considerably in effectiveness and permanence of film. An indication of this degree is illustrated in Tables I and II.

Watch for the March Issue

The March issue of ILLUMINATING ENGINEERING will have the latest and most complete listing of I.E.S. Committee personnel. Many additions have been made since the December 1951 listing and many new committees have been formed. These changes and complete personnel will be found under the heading "Committees" in the March issue of IE.

A Study of The Conspicuity of Orange Surface Colors

By W. E. KNOWLES MIDDLETON

A PAINT variously known as International Orange* and Aviation Orange** has been widely used for marking obstructions at airports, and for other purposes. This is an orange chrome having the approximate co-ordinates

$$x = 0.610,\ y = 0.362,\ Y = 0.14.$$

It occurred to the writer that this color might not in fact be the most conspicuous orange color when seen against practical backgrounds. Because of the influence of the atmosphere,[1] full scale tests are necessary to determine this point.

Experimental Arrangements

It happens that the writer's laboratory commands an extensive view over a terrain that provides a number of varieties of background. In particular, there is a large hydroelectric plant at a distance of about six and one-quarter miles, with a dam which faces the laboratory, and is surmounted by six steel frames at intervals of about 60 feet. With the permission of the Gatineau Power Company, six panels, each 8 feet square, were attached to these frames in July 1950, and painted with the six orange and yellow colors described below. As shown in Fig. 1, taken from the roof of the laboratory, the panels appeared against a background of vegetation, which is actually about a mile beyond the dam. The panels faced nearly due south and thus were illuminated by the sun for all observations when it was not obscured by clouds.

Observations were made three times a day, usually by four observers, all with normal color vision, on all occasions when the dam was visible. The observers looked first with the naked eye, then through 7×56 binoculars. They were asked to indicate the order of conspicuity of the six panels as a chromatic signal both with and without the visual aid, and to make any remarks that occurred to them about the appearance of the colors. One of the observers was delegated to estimate the visual range on each occasion, and to record the general state of the weather.

Although none of the observers was aware of the identity of the different colors, it was thought well to interchange the panels on September 5, 1950. Observations were continued until the end of November, when it was decided to look for another site which would provide a uniform snow background. A suitable hillside was found, 4¼ miles to the north of the laboratory. The panels were reduced to 6 feet square and erected in two rows, care being taken to have their faces vertical and parallel. Fig. 2, taken from a nearby point, shows the arrangement; but it should be remarked that, as seen from the laboratory, all the panels were well below the horizon. The somewhat irregular arrangement was adopted for the purpose of avoiding a gully which descends the hill diagonally.

At 6¼ miles, the 8-foot square panels subtended an angle of 0.85 minutes of arc, or 6.0 minutes as seen through the seven-power binoculars. The 6-foot square panels used at 4¼ miles subtended 0.91 minutes and 6.4 minutes respectively.

On January 19, 1951, some changes were made in the arrangement of the colors, and observations continued against a snow background until early in March.

Later in the spring observations were resumed for a short time, the background being light brown withered grass and herbage at first, and finally (in May and June) fresh green grass.

The Colors

In addition to commercial aviation orange, five other glossy paints were employed in this investigation, four being specially mixed by the Protective Coatings Section of the Division of Applied Chemistry. Five of these six colors formed a series ranging from bright yellow to a deep reddish orange; the sixth was designed to be similar in hue to aviation orange but of lower saturation, to correspond to a weathered surface of that paint. The chromaticity co-ordinates, luminous reflectance, and Munsell re-notation of these six colors are shown in Table I. It may be well to draw attention to the fact that the first five colors form a series of decreasing reflectance.

*Federal Specification TT-P-59, 2 February 1945; more recently TT-C-595, 12 January 1950. This is a gloss color 1205 in the latter specification.

**International Civil Aviation Organization document AGA Sub 2-WP/2, 15 November 1949, "Specifications for aviation colours and aviation surface colours."

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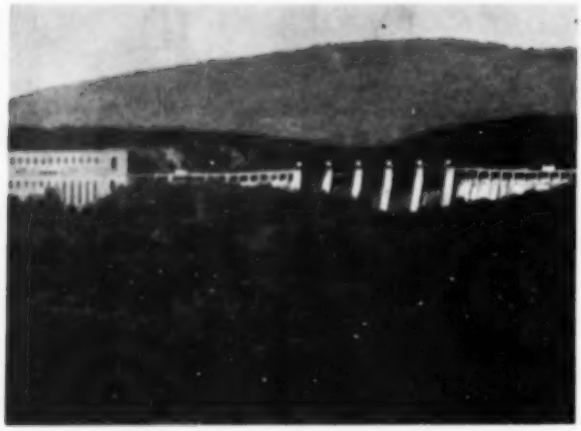


Figure 1. The six 8-foot-square panels, mounted on steel frames, as seen from the roof of the laboratory 6¼ miles distant. The panels are facing nearly due south to obtain a maximum of sunlight for the observations.

During the course of the winter the paints deteriorated somewhat, and late in April 1951 they were all re-painted. Colors 1 and 2 seemed to be most greatly affected, having darkened a good deal.

Results

The results are shown in Tables II to V. In these tables, each line represents a color, and the numbers in each column the corresponding number of times that it was adjudged most conspicuous, second, third, etc., in conspicuity, or not visible at all. Since there were many occasions on which two or more colors appeared equally conspicuous and were rated in their common position, the columns will not all add to the total number (N) of observations. The column headed "score" was arrived at as follows: The number of times a given color was the most conspicuous was multiplied by 6, the number of times it was second in order by 5, and so on, and the products added.

The observations fall into three groups, according to whether the background is forest, snow or grass. Each group has been further divided into two sub-groups, according to whether the sun was shining on the face of the panels or not. In the case of the forest background, a certain number of observations were made without field glasses (Table II); these have been separated from those using the 7×56 binoculars (Table III). Against the other backgrounds the panels were infrequently visible to the naked eye, and almost never as *chromatic* signals.

TABLE I.—Description of the Six Colors Used.

No.	Composition	Reflectance Y	Chromaticity Co-ordinates x	y	Munsell Notation	
1	Medium Chrome Yellow	.512	.501	.471	1.5Y	7.5/15.2
2	Aviation Orange & Med. Chrome Yellow	.226	.573	.407	3YR	5.5/15.0
3	Aviation Orange	.142	.608	.363	0.5YR	4.3/14
4	Aviation Orange & Toluidine Red	.114	.620	.339	9R	3.9/16
5	Aviation Orange & Toluidine Red	.086	.654	.321	8R	3.4/16
6	Aviation Orange & Light Chrome Yellow	.121	.568	.373	1YR	4.0/12.4

Discussion

A cursory inspection of the tables reveals that no one color is most conspicuous against all backgrounds. This is indeed to be expected because of the wide range of reflectance found in the backgrounds, from less than 0.1 (forest) to about 0.8 (snow). What does not emerge from the tables is that color No. 1, a bright yellow, while most conspicuous against all the darker backgrounds, cannot be considered a satisfactory *chromatic* signal at all. When seen from a distance this color frequently resembles that of a patch of sand or light soil, and indeed the sandy slopes visible between the dam and the powerhouse in Fig. 1 often proved to be a close match for it. In the following discussion, therefore, we shall confine our attention to colors 2 to 6.

Against the forest background (Tables II and III) the order of conspicuity of colors 2 to 5 is the order of their reflectances. This is in accord with the common observation that small differences of lightness are more noticeable than small differences in chromaticity. But the surprisingly low scores of No. 6 merit further discussion. This was the color designed to simulate weathered or slightly soiled aviation orange; and in spite of the fact that its

TABLE II.—Forest Background. No Visual Aid.

A. Sun shining on panels. N = 152

Color	Order of Conspicuity 1	2	3	4	5	6	Not Visible	Score
1	152	—	—	—	—	—	—	912
2	—	95	1	—	—	—	56	479
3	—	1	28	2	—	—	121	123
4	—	8	17	4	—	—	123	120
5	—	—	—	2	—	—	150	6
6	—	—	1	—	—	—	151	4

B. Sun not shining on panels. N = 143

Color	Order of Conspicuity 1	2	3	4	5	6	Not Visible	Score
1	142	—	—	—	—	—	1	852
2	1	79	—	—	—	—	63	401
3	—	1	26	—	—	—	116	79
4	—	1	—	1	—	—	141	8
5	—	1	—	1	—	—	141	8
6	—	1	—	—	—	—	142	5

TABLE III.—Forest Background. 7×56 Binoculars.

A. Sun shining on panels. N = 280

Color	Order of Conspicuity 1	2	3	4	5	6	Not Visible	Score
1	271	2	1	1	4	1	—	1652
2	8	256	8	7	1	—	—	1383
3	8	10	236	22	3	1	—	1115
4	4	13	31	131	94	7	—	801
5	10	5	18	132	107	6	—	775
6	—	3	9	12	51	205	—	394

B. Sun not shining on panels. N = 435

Color	Order of Conspicuity 1	2	3	4	5	6	Not Visible	Score
1	419	6	4	3	2	1	—	2574
2	9	405	12	3	1	—	5	2138
3	9	30	348	31	2	—	15	1693
4	3	21	53	235	94	13	26	1211
5	4	13	28	141	149	68	32	990
6	—	13	15	36	134	208	29	709

TABLE IV.—Snow Background. 7×56 Binoculars.

A. Sun shining on panels. N = 78

Color	Order of Conspicuity 1	2	3	4	5	6	Not Visible	Score
1	11	13	11	2	10	31	—	232
2	4	36	25	6	5	2	—	334
3	61	9	7	1	—	—	—	442
4	—	5	23	40	11	—	—	255
5	2	15	20	26	11	4	—	371
6	—	—	2	9	40	27	—	142

B. Sun not shining on panels. N = 95

Color	Order of Conspicuity 1	2	3	4	5	6	Not Visible	Score
1	7	5	13	8	16	40	6	315
2	5	45	20	13	3	—	4	395
3	78	9	7	—	—	—	1	541
4	14	10	33	25	10	—	3	311
5	8	30	18	23	12	—	4	363
6	4	6	8	10	35	24	8	210

TABLE V.—Grass Background. 7×56 Binoculars.

A. Sun shining on panels. N = 89

Color	Order of Conspicuity 1	2	3	4	5	6	Not Visible	Score
1	60	7	7	5	—	9	1	447
2	2	26	16	21	20	4	—	313
3	23	30	27	5	4	1	—	414
4	8	23	25	32	1	—	—	334
5	1	4	13	24	31	17	—	225
6	—	1	2	3	39	54	—	134

B. Sun not shining on panels. N = 197

Color	Order of Conspicuity 1	2	3	4	5	6	Not Visible	Score
1	162	9	10	12	2	1	1	1098
2	2	69	29	30	28	9	30	625
3	31	56	65	7	4	—	34	755
4	—	37	43	80	19	5	34	577
5	1	4	17	40	59	37	39	369
6	1	1	5	12	42	94	42	245

reflectance lay between that of Nos. 3 and 4 its performance is very much worse, especially in sunshine and without visual aids. The observations with the naked eye are of course in the region of small subtense investigated by Middleton and Holmes,[2] and it is probable that the relatively small difference in saturation leads to a large difference in apparent chromaticity under these conditions, although data are lacking for these particular colors.

Against the snow background (Table IV) it is evident that aviation orange is superior to all the

Figure 2. The panels seen with a snow background (photo taken from a near-by point). As seen from the laboratory, 4¼ miles distant, all the panels were well below the horizon.

other colors studied. It seems certain that other factors than reflectance entered into this judgment, as should be the case if the instructions to the observers were being followed. Again No. 6 makes a poor showing.

The slight superiority of No. 3 was maintained against the grass background (Table V), though the differences between 2, 3, and 4 are not great.

Throughout the tables it is evident that the differences between colors are much more pronounced when the sun is shining. The vertical panels will of course be relatively more strongly illuminated than the inclined backgrounds under these circumstances.

Recommendations

From the above results it may fairly be concluded that the present aviation orange (No. 3) is the most conspicuous color among those chosen when the whole range of natural backgrounds is taken into account, although a somewhat yellower and lighter color is certainly more conspicuous against a dark forest. This property of aviation orange was predicted on theoretical grounds in reference 1. An aircraft operating regularly over uninhabited country may well have the upper surfaces of its wings painted in aviation orange in order to maximize the chances of finding it if it should be forced to land.

It is also likely that aviation orange, consisting as it does of a simple chrome pigment, will be the best that can be produced from common materials. Obviously another color of the same hue and equal or greater reflectance and/or chroma might be as good or better, but the question of stability is of course very important.

The second conclusion which may be drawn from these data is that it is essential to keep this color clean and fresh, or in other words to maintain a high chroma. Color No. 6, which gave such poor results throughout, could easily pass for a moderately weathered specimen of aviation orange. The present paper may be considered to document the necessity for maintaining these orange paints in very good condition.

Although the subject is not directly connected with this paper, it may nevertheless not be superfluous to point out some very good reasons for avoiding the use of yellow as a color for aircraft, life rafts, and other objects which have to be seen from a great distance.

In a subsidiary investigation, small cubical blocks painted in various colors were hung on a fine wire at such distances that they subtended one minute or alternatively two minutes of arc, and were presented one at a time to four observers against backgrounds of grass, water, and pavement. The observers were required to name the color of each block, using only the terms black, white, red, orange, yellow, green, blue, and purple. The results of these experiments showed a complete, though of course qualitative agreement with the laboratory data described in reference 2. For our present purpose we shall only record that a yellow approximating Munsell 5Y 8.5/14 was frequently named white at a subtense of one minute of arc, while a bright orange was always named correctly.

These experiments were carried out at distances too short for the atmosphere to have an appreciable effect on the colors. As shown in reference 1, yellows will appear greenish at moderate distances in clear air, rendering it still more likely that they will be confused with white. Orange, on the other hand, shows relatively little change of hue with distance.

For both visual and atmospheric reasons, therefore, yellow is a poor choice for such applications.

The writer is glad to record the co-operation of the Gatineau Power Company and of Mr. Kenneth Kerr of West Templeton, Quebec, in permitting the erection of the panels on their properties; and also to thank Mr. J. Harris of the Division of Applied Chemistry for his care in mixing several of the paints used.

[1] W. E. K. Middleton, *J. Opt. Soc. Am.*, 40, 373 (1950).
[2] W. E. K. Middleton and Marian C. Holmes, *J. Opt. Soc. Am.*, 39: 582 (1949).

New Home Lighting Data Packet Now Available

A new packet of ten latest Home Lighting Data Sheets has just been approved by the sub-committee and is now available. Referred to as Home Lighting Packet #2, the group includes Data Sheets 22-20 through 22-29, all the new sheets prepared since the first packet in February 1950. They include lighting installations for a Glass Block Window, a Window Wall and Terrace, a Den, a Dining-Room, an Apartment Bedroom, a Hallway, an Apartment Living-Room; also, Decorative Lighting Effects, Mirror Lighting Applications, Soffit Lighting a Kitchen.

Many utility home lighting departments have ordered the first packet and will find Packet #2 equally helpful in furnishing new ideas and practical lighting information. Home Lighting Packet #2 is available at 50c from Publications Office, Illuminating Engineering Society, 1860 Broadway, New York 23, N. Y. A limited number of the first packet (23 sheets) can also be obtained at $1.25 each; or $1.00 on orders of 25 or more sets.

Relation of Distance to Candlepower Distribution From Fluorescent Luminaires

By CAROLINE E. HORN
WILLIAM F. LITTLE
ERNEST H. SALTER

THE VALIDITY of the inverse square law is only realized when the source is relatively a point. In the early days of the Illuminating Engineering Society, Dr. Louis Bell established the five times ratio. At that time, this five times ratio referred to a round symmetrical source where the minimum photometric distance was at least five times the diameter of the source. This, of course, included whatever accessory surrounded the lamp. Then the light sources were principally flames, gas mantles, arcs and carbon filaments. A few line sources, such as the Cooper-Hewitt[1] lamps, were available. Later work done by Dr. Rosa of the Bureau of Standards[2] indicated the relation between photometric distances and various types of sources for accurate light measurements. More recently Dr. Middleton, in connection with the author's paper at the Quebec Conference, pointed out the difference in photometric effect of the two ends of the tubular fluorescent lamp when viewed at an angle off normal to the lamp axis.

With the introduction of the fluorescent lamps, attention has again been focused upon the relation of candlepower to light source dimension and photometric distance. The laboratories measuring these luminaires have used distances anywhere from 2½ to 5 times the length. In some cases even shorter distances have been used.

Experiments made and reported at the Quebec Conference[3] showed deviations from the inverse square law for line sources where the distance-source length dimensions varied from 1-1 to 10-1 (Fig. 1).

All measurements were made using a barrier layer cell in connection with a "zero resistance" potentiometer indicator. In each case this was adjusted to read 1000.0 at nadir. Observations were made to the nearest 5 parts in 10000. This assembly had been checked for linearity of response over the range used.

To study the deviations which might occur, a 48-inch T12 fluorescent lamp was operated from a voltage regulated a-c line and measurements made as the lamp was revolved about a vertical axis, first with the lamp vertical and its axis corresponding to the axis of rotation, second with the lamp horizontal and its center at the axis of rotation, and finally, with the lamp at 45° to the vertical. In other words, distributions were made according to the three-plane method usually applied to fixtures. The distribution around the lamp when in the vertical position is, of course, a circular pattern of a value corresponding to that at nadir in the other two planes. Photometric distances were selected corresponding to approximately 1, 2, 3, 4, 5 and 6 times the maximum dimension or 4, 8, 12, 16, 20 and 25 feet.

The data and computations resulting from these readings are shown in Tables I, II and III. The data in the tables are taken from a single series of measurements.

A second series of data was taken to verify the

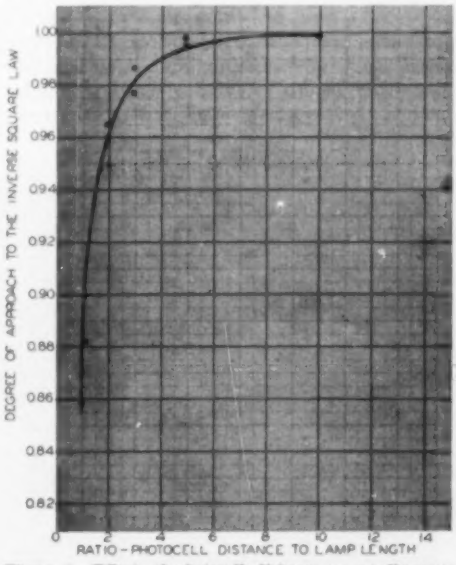


Figure 1. Effect of photocell distance on candlepower measurements of fluorescent lamps.

A paper presented at the National Technical Conference of the Illuminating Engineering Society, August 27-30, 1951, Washington, D. C. Authors: Electrical Testing Laboratories, New York, N. Y.

TABLE I.—40-Watt Lamp Alone.

Candlepower Distributions in Plane Through Axis of Lamp.

Angles	Lumen Factors	At 4 ft		At 8 ft		At 10 ft*		At 12 ft		At 16 ft		At 20 ft	
		Cp	Lumens	Cp	Lumens	Cp	Lumens	Cp	Lumens	Cp	Lumens	Cp	Lumens
90		1000		1000		1000		1000		1000		1000	
85	1.091	998	1089	996	1087	996	1086.6	996	1087	996	1087	995	1086
75	1.038	984	1041	963	1018	963	1017.8	981	1017	980	1016	958	1014
65	0.992	953	948	899	893	893	886.7	889	883	884	878	882	876
55	0.897	900	807	802	719	791	709.5	784	703	777	697	772	692
45	0.774	815	631	673	521	661	511.6	650	503	640	495	635	491
35	0.628	685	430	512	322	500	314.0	489	307	479	301	474	298
25	0.463	497	230	335	155	323	149.5	314	145	307	142	302	140
15	0.283	247	70	157	44	151	42.7	148	42	145	41	146	41
5	0.095	43	4	24.5	2	25	2.4	25	2	25.7	2	26.5	3
0		0		0		0		0		0		0	
Total			5248		4761		4721		4689		4659		4641
× 2			10496		9522		9442		9378		9318		9282
Ratio L/Cp			10.496		9.522		9.442		9.378		9.318		9.282

*Interpolated.

results; both series are plotted on semi-log paper (Fig. 2) to indicate the consistency of observations. Here the photometer indications at each angle of observation are plotted for each of the five photometric distances used. Data from one series are plotted as crosses; from the second, as points. Those angles showing the superscript "P" (parallel) correspond to tests with the lamp horizontal; those using the superscript "D" (diagonal), with the lamp 45° to the vertical.

An examination of the results shown in Tables I and III shows that the same ratio of lumens to candlepower is obtained at a given photometric distance whether the axis for distribution be taken through the lamp axis using data obtained in the "parallel plane" only or taken from an axis perpendicular to the lamp using the weighted average of the three planes, parallel, 45° and normal. This latter method, as usually applied to the photometry of fluorescent fixtures, gives the 45° plane double weight in the averaging. The fact that the lumen-candlepower ratios are in such close agreement between these two procedures would appear to justify the three-plane method of computation. It should be noted also that this agreement is obtained for the condition where differences between the three planes probably is greatest. Fig. 3 shows how this ratio is affected by the photometric distance.

The results of photometric tests of fluorescent lighting fixtures usually are expressed in terms of the average published light output of the lamps used. That is to say, the lamp lumens become the reference point for all computations. To accomplish this end the photometer is "standardized" through a measurement made at nadir of the lamp or lamps alone without benefit of fixture parts. Then a second measurement made at nadir with the full fixture in position serves to evaluate the

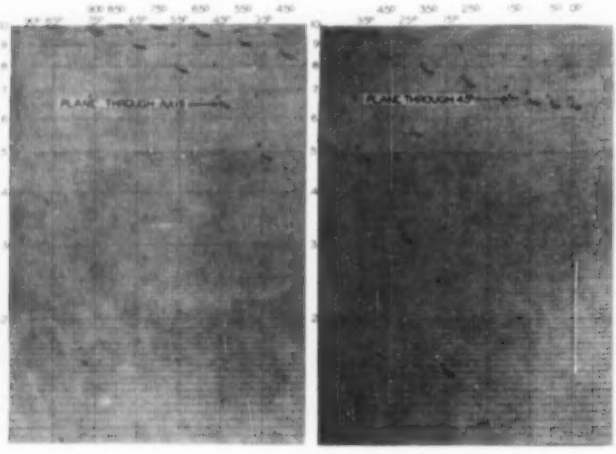


Figure 2. Candlepower distribution data plotted for five photometric distances.

TABLE II.—40-Watt Lamp Alone.
Candlepower Distribution in Three Planes.

Angle	At 4 ft				At 8 ft				At 12 ft				At 16 ft				At 20 ft			
	Parallel	45	Normal	Avg 1:2:1	Parallel	45	Normal	Avg 1:2:1	Parallel	45	Normal	Avg 1:2:1	Parallel	45	Normal	Avg 1:2:1	Parallel	45	Normal	Avg 1:2:1
0	1000	1000	1000		1000	1000	1000		1000	1000	1000		1000	1000	1000		1000	1000	1000	
5	998	1000	1000	999.5	996	998	1000	998.0	996	998	1000	998.0	996	998	1000	998.0	995	996	1000	996.8
15	984	995	1000	993.5	982	985	1000	983.0	981	982	1000	981.3	980	982	1000	981.0	958	981	1000	980.0
25	953	945	1000	940.8	889	955	1000	952.3	889	950	1000	947.3	884	951	1000	946.5	882	947	1000	944.0
35	900	964	1000	957.0	862	913	1000	907.0	784	900	1000	895.0	777	896	1000	892.3	772	893	1000	889.0
45	815	937	1000	923.3	673	858	1000	847.3	650	841	1000	833.0	640	838	1000	829.0	635	832	1000	824.8
55	685	905	1000	873.8	512	799	1000	777.5	489	777	1000	760.8	479	773	1000	758.3	474	769	1000	753.0
65	497	873	1000	810.8	335	744	1000	705.8	314	719	1000	688.0	307	713	1000	683.3	302	713	1000	682.0
75	247	844	1000	733.8	137	699	1000	638.8	148	673	1000	623.5	145	668	1000	620.3	146	663	1000	618.0
85	42	826	1000	673.5	24.5	675	1000	593.8	25	647	1000	579.8	25.7	642	1000	577.5	26.5	638	1000	575.8
90	0	825	1000	662.5	0	671	1000	585.5	0	648	1000	571.0	0	638	1000	569.0	0	634	1000	567.0

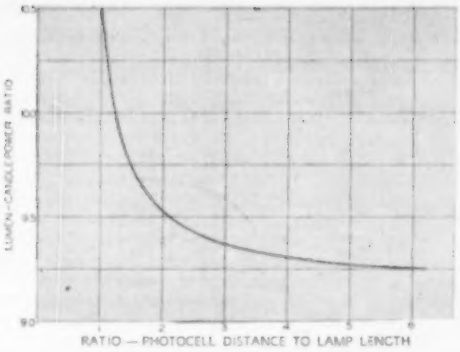


Figure 3. Lumen-candlepower ratio.

candlepower at nadir for the complete fixture assembly. All distribution curves then are equated at this point.

The data here presented for the lamp alone show that the apparent candlepower at nadir is a function of the distance of the measuring instrument from the lamp. The ratio of lamp lumens to apparent candlepower at nadir being 9.25 at 25 feet from 40-watt T-12 lamp, 9.37 at 12 feet, 9.52 at 8 feet and 10.49 at 4 feet (Fig. 3). In other words, for a given value of lamp lumens the apparent candlepower at nadir becomes progressively less as the distance from the lamp is reduced.

When measuring a multi-lamp fixture the effect of the inter-reflections between lamps must also be taken into account in the calibration. This may be done either by placing low reflectance screens between the lamps or by making a correction based on a study of these interreflection effects. A study was made of the increase in candlepower resulting from interreflection between lamps. This study included 2, 3, 4 and 6 lamps mounted side by side with varying spacing dimensions, and for different lamp sizes. Fig. 4 shows the per cent candlepower increase due to interreflection for T12 lamps. Where measurements of lamps alone are made without benefit of nonreflecting shields between the lamps this correction must be applied to the apparent candlepower determination at nadir. A glance at the curves of Fig. 4 will show that this correction may amount to 10 per cent or more.

Examination of the data presented in Tables I and III will indicate that when equated to the same lumen output, not only will the candlepower at nadir be lower at the shorter photometric distances, but that the shape of the distribution curves in the various planes and of the average curve will be different at the various distances. As an example of these effects the differences as

TABLE III.—40-Watt Lamp Alone.

Average Distribution by Three-Plane Method.

Angles	Lumen Factors	At 4 ft		At 8 ft		At 10 ft*		At 12 ft		At 16 ft		At 20 ft	
		Cp	Lumens	Cp	Lumens	Cp	Lumens	Cp	Lumens	Cp	Lumens	Cp	Lumens
0		1000		1000				1000		1000		1000	
5	0.095	999.5	95	998.0	95	998	94.8	998.0	95	998.0	95	996.8	95
15	0.283	992.5	281	983.0	278	982	277.9	981.3	278	981.0	278	980.0	277
25	0.463	980.8	454	952.3	441	949	439.4	947.3	439	946.5	438	944.0	437
35	0.626	957.0	601	907.0	570	906	565.2	896.0	563	892.3	560	889.0	558
45	0.774	922.3	714	847.3	656	839	649.4	833.0	645	829.0	642	824.8	638
55	0.897	873.8	784	777.5	697	769	688.9	760.8	682	756.3	678	753.0	675
65	0.993	810.8	805	705.8	701	695	690.0	688.0	683	683.3	679	682.0	677
75	1.058	733.8	676	638.8	676	629	665.5	623.5	660	620.3	656	618.0	654
85	1.091	672.5	735	593.8	648	583	636.2	579.8	633	577.5	630	575.8	628
90		662.5		585.5				571.0		569.0		567.0	
Total			5245		4762		4709.3		4678		4656		4639
× 2			10490		9524		9418		9356		9312		9278
Ratio L/Cp			10.490		9.524		9.418		9.356		9.312		9.278

*Interpolated.

indicated in Table III for the varying photometric distances were applied to the results of tests of an open-end RLM unit and a deep troffer. The resulting distribution data are shown in Tables IV and V.

These tables indicate that apparent efficiencies will vary with photometric distance depending on the shape of the distribution. A narrow beam unit such as the troffer for which data are given in Table V will show a decreased output and hence a lower efficiency when photometered at short distances. On the other hand, the RLM type of unit shows a small increase in output and efficiencies under these same conditions: Table IV. A fixture with a broader beam pattern would show further increase in output and efficiency at these shorter distances.

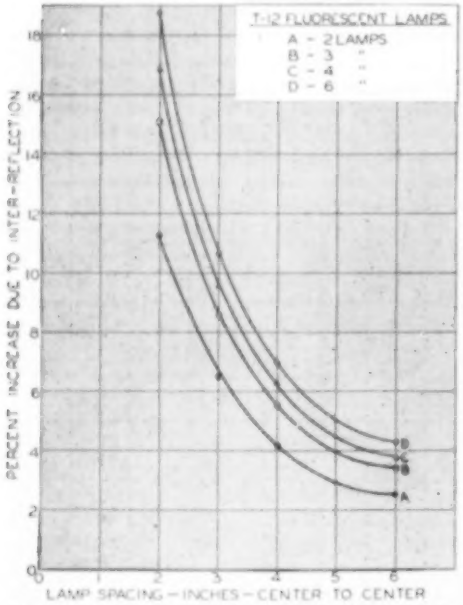


Figure 4. Correction curves for inter-reflection errors for spacing and number of lamps.

In both cases cited it will be noted that the apparent candlepower at nadir and the apparent flux in the zones up to 40° are markedly decreased at short distances. Where a candlepower ratio at some particular angle is specified this ratio may likewise be appreciably affected by the photometric distance used (see Table IV, Cp. ratio—55°).

The data indicate that, correcting for the lumen-candlepower ratio, correct luminaire efficiencies can be secured at distances down to about 2 × lamp length, and each series of candlepower distribution data is correct for that distance. On the other hand, the candlepower distributions for

TABLE IV.—Comparison of Computed Photometric Data For a Typical Open-End RLM Unit.

Angle	At 4 ft		At 8 ft		At 25 ft	
	Avg Cp	Lumens	Avg Cp	Lumens	Avg Cp	Lumens
105	0	0	0	0	0	0
95	3	3	3	3	3	3
90	10	—	11	—	11	—
85	71	78	59	64	60	65
75	359	580	306	324	300	317
65	754	749	682	674	670	665
55	1081	970	1017	913	1000	897
45	1368	981	1373	996	1270	983
35	1396	876	1453	912	1460	917
25	1467	680	1567	726	1600	741
15	1491	423	1625	460	1660	470
5	1500	142.5	1650	157	1690	161
0	1496	—	1648		1690	
Total lumens		5262		5232		5219
Lamp lumens		6600		6600		6600
Efficiency		80.1		79.3		79.0
Lumens 0-30		1245		1343		1372
0-40		2121		2255		2289
0-60		4071		4163		4169
Cp Ratio 55°		0.640		0.618		0.592

TABLE V.—Comparison of Computed Photometric Data For a Narrow-Beam Troffer.

Angle	At 4 ft Avg Cp	At 4 ft Lumens	At 8 ft Avg Cp	At 8 ft Lumens	At 25 ft Avg Cp	At 25 ft Lumens
90	0		0		0	
85	5	5.5	4	4.4	3.8	4
75	26	27.5	22	23.3	21.3	23
65	61	60.6	53	52.6	50.5	50
55	115	103.2	106	95.1	104	93
35	378	237.4	394	247.4	397	249
45	219	169.5	217	168.0	215	166
25	496	230.6	532	246.3	540	250
15	586	166.4	648	183.4	660	187
5	638	60.8	701	66.6	720	68
0	644		709		730	
Total lumens		1061		1067		1091
Lamp lumens		2300		2300		2300
Efficiency		46.2		47.3		47.5
Lumens 0-40		695		744		754
0-60		998		1007		1013

infinity distance are desirable when computations are to be made, utilization coefficients established or design characteristics verified. Mr. Kurt Franck[4] in his paper brings out the theoretically desirable practice of considering a long unit as made up of a series of short units each of which is sufficiently small to approach and act as a point source. Unfortunately Mr. Franck's suggested method involves measurement difficulties even beyond those cited above.

It is recommended, therefore, that regardless of the photometric distance used, the distribution data on the basis of at least 5 times the maximum dimension should be used.

Where space limitations preclude the use of a reasonable photometric distance (five to one), data may be obtained provided full compensation is made for deviation from true candlepower distributions.

The studies show that line sources and fluorescent units can be tested and results simulating infinity distance can be secured for short photometric distances provided the individual observations in each plane are corrected through the use of factors obtainable from the data shown in this paper. These corrections carry back even to the observations of the lamp alone.

References

1. Pole, Joseph C.: "Photometry of Mercury Vapor Lamps," pp. 306 and 521, and Jones, Bassett, *Jr.*: "The Polar Curves of Definite Lines and Surface Sources," p. 365, *Transactions of the Illuminating Engineering Society*, Vol. V (1911).

2. Ross, Edward B.: "Photometric Units and Standards," *Lectures on Illuminating Engineering*, Vol. I, p. 387, Johns Hopkins University (1910); and "Photometric Units and Nomenclature," p. 473, *Transactions of the Illuminating Engineering Society*, Vol. IV (1910).

3. Little, William F. and Salter, Ernest H.: "The Measurement of Fluorescent Lamps and Luminaires," ILLUMINATING ENGINEERING, Vol. XLII, p. 217 (1947).

4. Franck, Kurt: "A Method of Testing and Evaluating Fluorescent Luminaires," ILLUMINATING ENGINEERING, Vol. XLV, p. 763 (December 1950).

DISCUSSION

KURT FRANCK*: The problem of photometrically obtaining true values of the main characteristics of a luminaire, such as true candlepower, true efficiency or output, etc., has become acute ever since fluorescent luminaires of considerable length were introduced. Several solutions have previously been suggested and the one contained in this paper adds to the stock of knowledge on the subject and is indeed welcome.

It seems to me that some of the statements in the paper are not expressed to best advantage. Sentences like "efficiencies will vary with photometric distance" or "candlepower at nadir and the flux in the zones up to 40 degrees are markedly decreased at short distances" might be misleading. A given luminaire has only one value of candlepower in any given direction and only one value of efficiency or output; these values are independent of the photometric test distance. Miss Horn and Messrs. Little and Salter know this, of course, but sentences like the ones quoted and several others in similar vein might have been worded more precisely.

This is just a detail. All in all, the authors have made a very worthwhile contribution to the problem of photometry of luminaires using extended light sources.

R. D. BRADLEY**: In studying the above paper by Messrs. Little, Salter and Miss Horn, I find that it is very constructive and will contain a lot of information that will be usable to laboratories testing equipment.

The authors have again established that in order to approximate point source illumination from linear sources, at least five times the source length should be used as a photometric distance. Unfortunately with some of our longer light sources this is not always practical from physical limitations, and the authors have disclosed a method by which shorter distances may be used with certain correction factors.

Most laboratories are troubled by the 8-foot light sources in that it is quite often difficult, if not impossible, to get at least a 40-foot photometric test distance. I would like to have the authors comment as to whether or not the relationships established for the 4-foot lamp would hold in the same ratio for the 8-foot lamp.

In studying this paper, I believe that Figure 3, "The Lumen Candlepower Ratio" diagram, should have a correction in the horizontal axis heading. I believe that this present heading, namely, "Distance—Feet" should have an explanatory note in that, undoubtedly the distance in feet should be multiplied by the source length in feet.

RAY P. TEELE†: The corrections worked out for the effect of photometric distance on candlepower and on lumen-candlepower ratio should prove very useful to laboratories which must use photometric distances shorter than 25 feet. The curves for evaluating the inter-reflection between lamps for various spacings of the lamps should save considerable time and trouble in testing multilamp luminaires.

The abscissa scale of Figure 3 is incorrectly marked. It should be Ratio—Photocell Distance to Lamp Length and not Distance—Feet. In the paragraph under Figure 3 the ratios given are for lamp lumens to apparent candlepower and not for the reciprocal ratio as stated in the text.

The values given for "Avg Cp" at 4 feet in Table IV

*Holophane Co., Newark, Ohio.
**Day-Brite Lighting, Inc., St. Louis, Mo.
†National Bureau of Standards, Washington, D. C.

seem to be wrong. They will not yield the 0.640 "Up Ratio 55°" given in the last line of the table.

CAROLINE E. HORN, W. F. LITTLE, E. H. SALTER*: The authors wish to thank Mr. Franck for his comments pointing out the looseness of expression in several paragraphs of the paper. Corrections have been made in line with his comments.

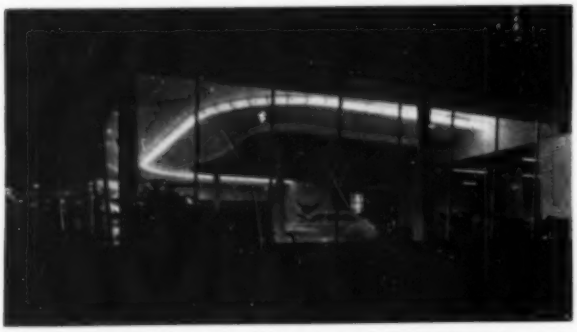
Mr. Bradley asks the authors' opinions regarding the relationships of photometric distances between 4- and 8-foot lamps. It is our opinion that so long as the dimensions are kept relatively the same, the data in the paper are pertinent. Therefore the tables and graphs should represent very closely the performance with respect to ratio of length to photometric distance.

The authors also wish to express their appreciation of the comments made by Mr. Teele.

*Authors.

Combination Lighting in Automobile Showroom

Interior view of showroom illustrates three types of general lighting and teardrop canopy.



Exterior view gives another angle on the center canopy, horseshoe band, primeter lights and teardrop canopy.

Three types of lighting are used in the passenger car showroom of Hopping Phillips Motors, Inc., Newark, N. J. Around the perimeter, recessed "eyeball" units are mounted on 16-foot centers, 14½ feet above the floor. These units contain PAR 38 lamps and can be adjusted in any direction up to 36 degrees from the vertical. In the center of the room a dropped ceiling area covers 950 square feet and is illuminated by 33 recessed incandescent downlights. Concentric multiple baffles trap spill light from the PAR 38 flood lamps. The ceiling is suspended two feet below the 16-foot main ceiling.

Between the perimeter lights and the dropped ceiling, a continuous surface-mounted fluorescent horseshoe provides general illumination. These specially designed units contain five lamps each. In all, 144 lamps illuminate 2000 square feet. Each row is separately circuited.

Duplex outlets in bases of columns provide for additional floor-based equipment when required. Teardrop entrance canopy, which extends indoors, has 100-watt lamps.

Illumination levels around the perimeter are 25 footcandles at hood height, 3½ feet above the floor. In the central area at hood height, intensities average at 38-40 footcandles. General illumination in the intermediate area, is between 35.7 and 43 footcandles.

The rear wall of the showroom is rusticated buff brick. Flooring is neutral gray-blue. The central canopy is dark brown and the rest of the ceiling is soft yellow to add warmth to the cool tone of the fluorescent lamps.

Architect and Lighting Designer: H. C. Litwack; Electrical Contractor for Lighting: A. L. Davis; Electrical Contractor for Power: Paul H. Jaehnig, all of Newark, N. J.

Lighting a File Room

LIGHTING OBJECTIVE: To provide adequate illumination in record file stacks.

Figure 1. Lower Deck.

Figure 2. Upper Deck.

Installation at Pennsylvania Company for Banking and Trusts
307 Chestnut Street, Philadelphia, Pennsylvania.

General Information: The lower deck, shown in Figure 1, is used continuously while material stored in the upper deck, Figure 2, is referred to only occasionally. The file cabinets are forest green (22% RF); the floor is covered in a light linoleum (46% RF); and the ceiling of the upper deck is gray (20% RF). Aisle width is 3 feet 6 inches; stack height is 9 feet.

Installation: The lower deck is illuminated by two rows (one along each side of the aisle) of 40-watt 48-inch single-lamp preheat-start fluorescent lighting units. Centered above the upper deck aisle is a single row of 75-watt 96-inch single-lamp instant-start units. All lamps are T-12's, warm white in color, and are mounted 9 feet 6 inches above the flooring.

Illumination and brightnesses measure as follows:

	Horizontal Footcandles		Footlamberts
	Lower Deck	Upper Deck	Lower Deck
Cabinets: at floor	32	17	7
4 feet up	51	25	12
9 feet up	105	46	23
Floor	32	17	14
Ceiling			4
Luminaire, lengthwise at 30 degrees from the horizontal (reflector, with lamp shielded from view)			1400

All lighting equipment was custom-built by the Keystone Electric Manufacturing Co., 2228 E. Tioga Street, Philadelphia, Pennsylvania.

Lighting data submitted by George T. Anderson, Jr. of the Philadelphia Electric Company as an illustration of good lighting practice and to aid in the design of similar installations.

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Circuiting for Uniformity of Design

Wiring Pattern Allows Economical Use of Lighting System

By JAMES O. JOHNSON

BEHIND the lighting design of our new office and plant, erected this past year at Hillside, N. J., there is a pattern not readily appreciated by the casual viewer. The lighting itself is to modern standards — comfortable, of a level of 45 to 50 footcandles in the offices, and of the order of 30 ft-c in the plant, with relatively good brightness ratios and high reflectance surfaces.

The circuiting, however, is of particular interest, we feel. In the shop, the lighting is laid out in an even pattern of 100 square feet per two-light, 40-watt, industrial fluorescent unit, each luminaire being spaced on an even 10' x 10' spacing, suspended 9' 6" from finished floor to the bottom of the reflector. Switch control for all of the lighting in the plant is limited to six light per circuit, each circuit being controlled and protected by a circuit breaker which is conveniently located in a lighting panel. Each luminaire has its own switch to allow for flexibility in the use of the lighting system.

In the manufacturing areas all outlets for luminaires are on even 10' x 10' pattern. In warehouse and storage areas bare T-outlet boxes are installed and spare T-outlet boxes are blanked for future use. To expand the manufacturing area, luminaires may simply be installed on these blank outlets.

The lighting design in the office affords flexibility of office partitioning especially important to a new plant where expansion and change may be anticipated. A general lighting level of 45 footcandles is provided by 55 two-light 40-watt luminaires, with glass panel sides and louver bottoms, ceiling mounted in three continuous rows, spaced on 8-foot centers. The area involved is 2720 square feet, with a 10-foot ceiling.

Here again, circuiting has a special pattern. Each five luminaires in a continuous run is separately controlled by use of a circuit breaker with the control panel centrally located at the main entrance from factory to office. Since only part of the space is now occupied, pending expansion, unused portions may be left lighted only with daylight. Economical use of the system may also be made after hours, when one or two eager beavers may work into the night without illuminating the entire area. Two night lights burn all night in both factory and offices, to aid police in their nighttime rounds.

Author: Buchanan Electrical Products Corp., Hillside, N. J. Data from Walter E. Turnbull, Public Service Electric and Gas Co., and Mel Winkel, Acme Electric Co., Elizabeth, N. J.

In photo at left, an electrician installs wiring for office shown at right. Switch control for all the lighting is limited to six lights per circuit, each luminaire being controlled from a conveniently located switch.

Color and Light in Modern Merchandising

By L. COURT BUTLER

Two views at the B. Altman store in White Plains, N. Y., where a "blend of fluorescent and incandescent is obtained on the merchandise level. Both the incandescent downlights and the recessed fluorescent units are designed for maximum spread. With this overlapping mixture of color quality of the lighting, maximum appeal is provided for the display of ladies dresses, in addition to the required levels of illumination.

DEVELOPMENTS in recent years in the field of illumination and particularly the advent of fluorescent lighting, tend to emphasize the manifold problems involved in lighting the modern department store. Ordinarily in planning the average industrial or commercial lighting installation, if the illumination is of an adequate level, well diffused, distributed, and shielded to protect the eyes from glaring sources, the installation is considered to be well engineered, in other words, a good lighting job. In lighting the modern store, however, these have become empirical factors — elementary to the following correlated considerations:

1. Customer reaction.
2. General effect on merchandise.
3. Suitability of spectral quality for various kinds of merchandise.
4. Adequacy of intensity for displays.
5. Proper use of accent lighting.
6. Proper application of complementary colors in decorations, store fixtures, floor coverings, etc. to neutralize adverse effects of spectral deficiencies in the wave-form of the light source.
7. The studied application of combinations of fluorescent-incandescent lighting to balance the spectral quality of the lighting where a close approximation of daylight values is desirable.

Human beings are more likely to become prejudiced in their seeing habits because of peculiarities in the wave-form of the lighting with which they are required to discern objects in form, outline, and color, than they are by inadequacies in the lighting. This is true, because we see objects by the light reflected from their surfaces, which reflect

Author: Court Butler-Lighting, Inc., Meriden, Conn.

only rays or wavelengths of light for which they have an affinity. In other words, an object reflects only the wavelength frequencies of the light impinging upon it which conform to the wave consistency of the electrons composing its surface.

The alchemy of color is only the chemistry of light, for just as there can be no light without color, even so, there can be no color without light, and there can be no true color seen except to the degree that it is contained in the wave-form of light. For example, an object that is red will reflect red rays only and one that is green, green rays, etc. Consequently, if light has an excess of green wavelengths and is deficient in red, the chroma of saturation of the green object will appear accentuated or intensified, and conversely, the color value of the red object will be attenuated or distorted, proportionally to the deficiency of this ingredient in the light.

Wavelength Distortion

Such irregularities of color rendition by artificial lighting are noticeable in the distortion of the long wavelength colors such as red and orange under fluorescent lighting, which is deficient in red, and of the amplification of short wavelength colors such as the blues and purples under this light regardless of rated kelvin color temperature. Conversely, incandescent light, which is strong in red, intensifies the long wavelength colors and tends to lessen the saturation of short wavelength colors. This also explains the heightening of the complexion under incandescent lighting and the pallid appearance of the complexion under gaseous discharge light such as mercury and sodium and to a degree under fluorescent light. Thus we see that the wave-form or spectral quality of light may induce either favorable or unfavorable psychological reactions and produce either a beneficial or detrimental effect upon the appearance of objects and consequently on the sales appeal of merchandise lighted.

One of the heads of the women's ready-to-wear department in one of the largest department stores in the East stated recently that many of their customers returned merchandise purchased in this department because the merchandise did not look the same after it left the store as it did on the sales floor. Yet this department was lighted by so-called warm tone fluorescent lamps which are presumed to provide a superior color quality of fluorescent light. Had this department been lighted with a proper combination of fluorescent-incandescent lighting such complaints could have been obviated.

However, modern technique in lighting the department store has evolved from the nebulae of empirical hypotheses into tangible and practical solutions to the various problems presented.

The lighting treatment for merchandise may vary according to the merchandise. This is particularly true of wearing apparel. For example, furs, such as mink, sable, marten, kolinsky, seal, ermine, and silver fox retain their true luster and color quality best under "cold light" such as fluorescent light because the habitat of such fur bearing animals in usually in the cold regions. An admixture of fluorescent and incandescent light or warm tone fluorescent with incandescent down lights is quite effective for general apparel, such as millinery, hosiery, street wear, lingerie, etc. On the other hand, shoes and evening wear seem to require a psychologically warmer atmosphere of illumination and look best under incandescent light. Piece goods, draperies, and carpets need either incandescent light or a proper admixture of fluorescent-incandescent lighting for best results. If this is not acceptable to the merchant, warm tone fluorescent light with adequate incandescent down lighting should prove effective.

It should be understood that fluorescent light contains but a modicum of the irritating infrared preponderant in incandescent light. This is why we are not as conscious of a given intensity of fluorescent light as we are of the same footcandle level of incandescent light. This also explains the sometime lack-luster and vapid appearance of fluorescent light and the need for combination fluorescent-incandescent light or at least, supplemental incandescent down lighting to add glow to the appearance of merchandise.

Color Influences Mood

The display man is constantly dealing with problems correlated to the psychology of color and although scientific data relating to the influence of color upon human behavior is limited, it is indicated that human sensibility to color is manifested in certain reactions, such as the sense of warmth produced by light of the adjectively warm red, yellow, and amber colors, and the opposite sensation of coolness always associated with blue, green, and bluish white light. It is further indicated that yellow and amber colored light produces a sense of stimulation, while green and bluish white light has a soothing effect, and that light composed of the short wavelength purple and violet rays is depressing. It may be said that the so-called phychological effects of the various colors of light correspond to the physiological reaction produced by these various wavelengths of colors upon the millions of nerve cells or receptors of the retina of the human eye.

Current Recommended Practice for Sports Lighting—Part II

Prepared by the Committee on Sports and Recreational Area Lighting of the Illuminating Engineering Society*

Part I of the Current Recommended Practice for Sports Lighting, comprising sections one through five, appeared in the November 1951 issue of ILLUMINATING ENGINEERING.

6. Typical Layouts for Indoor Sports

6.1—*General*—Sports played indoors may be generally divided into two classes: (1) sports played within one general area, i.e., gymnasiums, where the lighting is provided by one lighting system, and (2) sports played in specific areas designed expressly for that sport with a lighting system designed specifically for that one sport.

6.2—*Gymnasiums*— (a) The school gymnasium is a multi-sport center which serves the student body during the daytime and in many cases the community at night. It is used for dances where the preferred lighting key is low and colorful, for assemblies where the lighting is primarily for atmosphere, for general exercise and recreation where the lighting assures safe and adequate performance, and lastly, for games and exhibitions where substantially higher levels are required both for players and spectators. The higher levels needed for exhibition events may be attained by means of a supplementary system.

(b) The illumination levels recommended for a gymnasium depend on the purposes for which the gymnasium is used (see Table I). Uniformity of illumination well within the maximum-minimum brightness ratio of 3 to 1 (paragraph 2.2.2) is particularly important for multi-sport gymnasium use and is readily attainable by proper design of the lighting system. Glare may be minimized by a choice of luminaires of low brightness at the higher angles and by the use of a ceiling of light color. Luminaires should be suitably protected from mechanical injury.

(c) In most cases these lighting requirements are met with general illumination from a direct lighting system. However, in some cases consideration is given to semi-direct or even indirect lighting systems. Where the gymnasium is to be used for inter-school games, the basketball court or other similar area should be provided with supplementary lighting from concentrating industrial type lighting units.

6.3—*Specialized Areas*—(a) This report contains typical layouts to illustrate good lighting practice for certain specialized sports usually played indoors. Illumination levels obtained with these typical layouts may be expected to meet substantially the I.E.S. recommended values. In any installation, the illumination obtained in subject to unpredictable variations in installation, reflectors and lamps within manufacturing tolerances, and in voltage at the lamps.

7. Design Factors

7.1—*General*—(a) The correct choice among the various design factors depends upon a balancing of economic costs against such factors as appearance, relative safety, and reliability.

(b) The overall cost for lighting should include: (1) an amortization of the first cost, (2) the cost of electrical energy consumed, (3) cost of lamp replacements, and (4) an estimate for maintenance expense exclusive of lamp replacement.

(c) Comparison of lighting systems on this basis, perhaps with different luminaires or different wiring methods, may be made by means of a cost analysis., A true comparison should involve systems providing comparable quality and quantity of illumination.

7.2—*Lamp Voltage*— (a) Many sports lighting installations are utilized for a comparatively small number of hours per year. In such cases good economy dictates the operation of the filament lamps at voltages above those for which they were designed. In general, operation of general lighting service lamps at 10 per cent over rated voltage should prove economical when filament lamps are in use 200 hours or less per year, and 5 per cent overvoltage operation when annual use is from 200 to 500 hours. Where annual operation exceeds 500 hours lamp operation at rated voltage is recommended. Operation at 10 per cent over voltage increases light output 35 per cent, power consumed, 16 per cent, and reduces lamp life to approximately one quarter of rated life. Operation at 5 per cent over voltage increases light output 18 per cent, energy consumption 8 per cent, and reduces lamp life approximately one half of rated life.

(b) The typical layouts in this recommended practice take advantage of over voltage operation where justified to reduce the amount of equipment required. While over voltage lamps are referred to in many layouts there is no expressed or implied restriction on the use of any other suitable lamp of equivalent output and life at rated volts.

7.3—*Choice of Equipment*—(a) Floodlights, due to their larger size, more elaborate mounting requirements, and in some cases cover glasses, are more expensive than normal indoor type luminaires. The use of floodlights is economically justified on any outdoor area where the light must be projected to a considerable distance. The comparison can readily be calculated by the methods outlined in Appendix D.

(b) Floodlights are available with beam spreads of various degrees and can be used economically to concentrate light on and near the playing area even when they must be mounted several hundred feet from the playing

*Approved by the I.E.S. Council, December 1950.

Figure 34. Twin-mounted individually-circuited filament luminaires provide a choice of illumination levels for practice and contests in this university gymnasium.

area. On the other hand, some of the playground sports such as horseshoe pitching, shuffleboard, etc. may in some cases be lighted by indoor type luminaires suitably adapted for outdoor use.

7.4—*Choice of Beam Spreads*— Most open floodlights provide inherently wide beam spread. Enclosed floodlights are available in a range of beam spreads from wide to narrow. The choice of beam spread depends largely on the distance from the floodlights to the area to be lighted; the greater the distance, the narrower the beam spread for high utilization efficiency. Although the cost of specularly-reflecting equipment is higher than that of wide-beam types the overall installation cost with specular reflectors is less when the floodlights are located at a considerable distance because fewer units are needed. Conversely, when floodlights are located relatively close to the playing area wide beam spreads can be used with good economy.

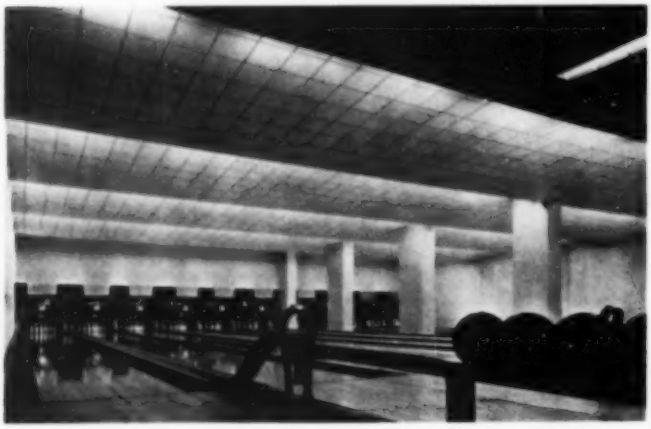


Figure 35. Light sources concealed by sawtooth ceiling construction give unidirectional lighting.

7.5—*Open and Enclosed Floodlights*— The choice between open and enclosed floodlights depends chiefly on differences in cost and in rate of depreciation. Open floodlights cost less, but depreciate more rapidly due to collection of dirt, soot, etc., on reflecting surfaces and light sources. It is generally accepted practice to allow a maintenance factor of 75 per cent for enclosed floodlights and 65 per cent for open floodlights when calculating the maintained footcandle level. The typical layouts are based upon these maintenance factors. Although these factors are empirical, they are based on considerable experience. The cleanliness of the surroundings, the frequency of cleaning of the units and replacement of lamps will affect the maintenance factor to a considerable extent.

7.6—*Reflectorized Lamps* — Reflectorized lamps may be used; their principle application is in small-scale sports lighting installations. Reflectorized lamps for outdoor use are made of heat resisting glass which will not crack when subjected to rain while in operation. The relative economy of using these lamps and associated equipment when compared with other lighting systems may be calculated for any installation.

7.7—*Wiring*—(a) Outdoor floodlighting installations are sometimes made with overhead wiring and in other cases with either direct burial underground cable or wire in a duct system which runs to the base of each pole or tower and extends up the tower in rigid conduit. The type of wiring to use depends on local practices and on economic factors including the value placed upon such items as appearance, safety, and reliability. In addition to the choice in method of wiring an economic study should be made of the method of distribution. Some installations justify a separate transformer on each pole or tower with primary wiring to each such location. In other cases it is more economical to reduce the number of transformers and run secondary wiring to some of the floodlight locations. The question of whether or not to individually fuse each floodlight is determined partially by local practice and partly by economic considerations.

Class	IES Current Recommended Practice—Footcandles Maintained in Service	Luminaires Required No.	Luminaires Required Type
Championship	500	36	Direct (concentrating distribution)
Professional	200	16	Direct (concentrating distribution)
Amateur	100	9	Direct (concentrating distribution)

LAMPS: 1000-watt clear general lighting service operated at 10% over rated voltage for Championship and Professional bouts.
MOUNTING HEIGHT: 18-20 feet above ring.

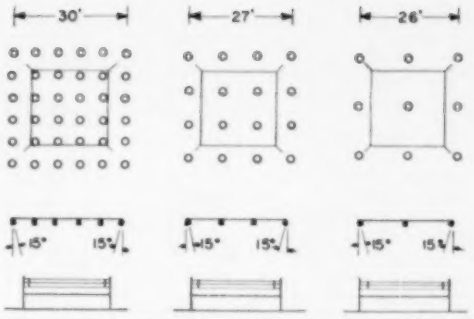


Figure 36. Typical Layout for Indoor Boxing or Wrestling Rings.

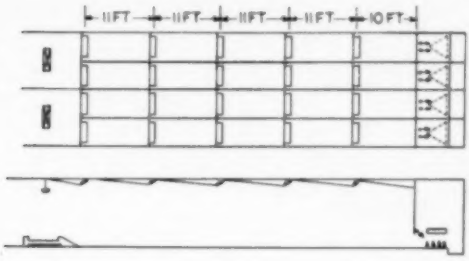


Figure 37. Typical Layout for Tournament Bowling.

Class	IES Current Recommended Practice—Footcandles Maintained in Service	Luminaires Required
Tournament	20 on alleys	Direct-indirect luminaire with with filament or white fluorescent lamps providing approximately 9200 lumens.
		Direct fluorescent or filament lamp unit providing approximately 4600 lumens.
	50 on pins	PAR-38 projector floodlamp, or 150-watt inside-frosted lamp in directional luminaire, or two 75-watt R-30 reflector floodlamps.

MOUNTING: Mount lane units on ceiling at approximately 30 degrees from horizontal. Mount floodlights behind shield close to pins.

Class	IES Current Recommended Practice—Footcandles Maintained in Service	Luminaires Required
Recreational	10 on alleys	Direct-indirect luminaire with filament or white fluorescent lamps providing approximately 4600 lumens.
		Direct fluorescent or filament lamp unit providing approximately 4600 lumens.
		Direct unit providing approximately 2300 lumens.
	30 on pins	PAR 38 projector floodlamp, or 150-watt inside-frosted lamp in directional luminaire, or two 75-watt R-30 reflector floodlamps.

MOUNTING: Mount lane units on ceiling at approximately 30 degrees from horizontal. Mount floodlights behind shield close to pins.

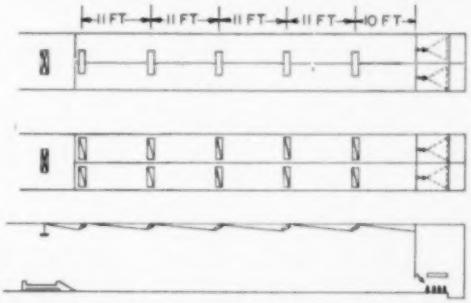


Figure 38. Typical Layout for Recreational Bowling.

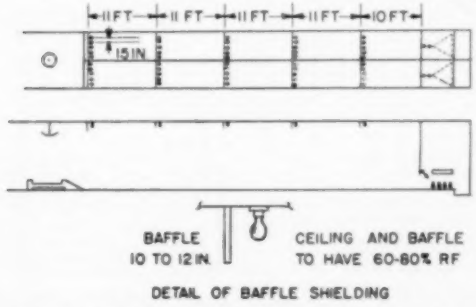
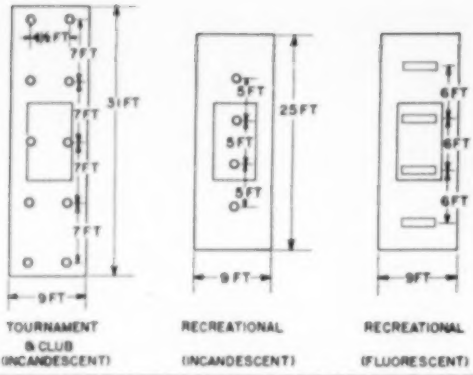


Figure 39. Typical Layout for Recreational Bowling Using Bare Filament Lamps and Baffles.

Class	IES Current Recommended Practice—Footcandles Maintained in Service	Luminaires Required
Recreational	10 on alleys	Semi-indirect unit with 300-watt inside-frosted general service lamp.
		Exposed 40-watt inside-frosted general service lamps.
	30 on pins	PAR-38 projector floodlamp, or 150-watt inside-frosted lamp in directional luminaire, or two 75-watt R-30 reflector floodlamps.

MOUNTING: Mount lane units on ceiling behind baffle. Baffles at first and second rows from foul line should be deeper than indicated above and possibly tilted to reduce specular reflection in polished lanes. To achieve the recommended footcandles the reflectance of baffles and ceiling must be maintained at 60% or better.



Class	IES Current Recommended Practice—Footcandles Maintained in Service	Luminaires Required No.	Luminaires Required Type
Tournament	50	10	Direct units (spread distribution) with 200-watt filament lamps.
Club	30	10	Direct units (spread distribution) with 140-watt filament lamps.
Recreational	20	4	Direct units (spread distribution) with 150-watt filament lamps or white fluorescent lamps supplying approximately 4600 lumens.

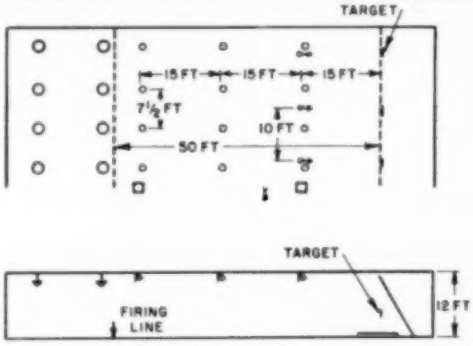
LAMPS: Inside-frosted general service filament lamps operated at 10% over rated voltage for Tournament Play and 5% over rated voltage for Club Play.

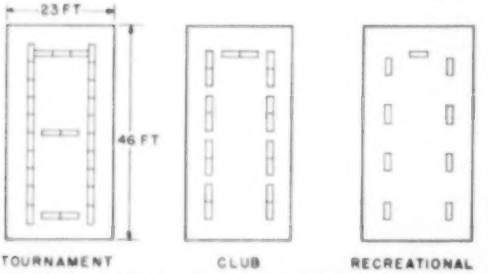
Figure 40. Typical Layout for Table Tennis.

IES Current Recommended Practice—Footcandles Maintained in Service	Symbol	Luminaire Designation	Lamp Watts
10 at firing point	○	Indirect	200
5 on range	○	Directional type aimed forward	100
50 vertical on target	—●	Floodlight—Type 5 Heavy Duty	500

LAMPS: Clear general lighting service operated at rated voltage.
CEILING HEIGHT: Approximately 12 feet.

Figure 41. Typical Layout for Indoor Rifle and Pistol Ranges.





Class	IES Current Recommended Practice—Footcandles Maintained in Service	Luminaires Required
Tournament	30	27 direct (spread distribution) luminaires, each with white fluorescent lamps providing approximately 4600 lumens.
Club	20	18 units as above.
Recreational	10	9 units as above.

MOUNTING: Recessed in ceiling, with cover glass; ceiling height 23 feet.

Figure 42. Typical Layout for Four Wall Handball (Indoor) Using Fluorescent Lamps. (Same or similar layout may be used for Squash.)

Class	IES Current Recommended Practice—Footcandles Maintained in Service	Luminaires Required
Tournament	30	19 direct (spread distribution) luminaires each containing one 300-watt inside-frosted lamp. Carefully shielded to avoid glare; silvered bowl lamps or diffusing media recommended.
Club	20	14 units as above.
Recreational	10	11 200-watt units similar to above.

MOUNTING: Recessed in ceiling, with cover glass; ceiling height 23 feet.

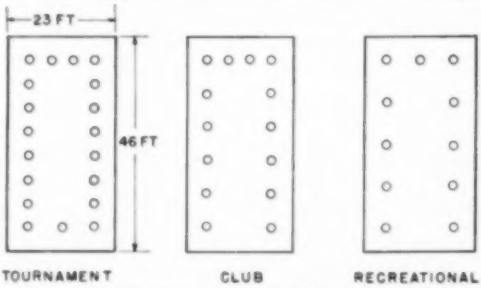


Figure 43. Typical Layout for Four Wall Handball (Indoor) Using Filament Lamps. (Same or similar layout may be used for Squash.)

Appendix A — Beam Characteristics and Photometric Performance of Floodlights

Heavy Duty Enclosed Floodlights — Class HD

Type	Beam Spread, Degrees	Beam Efficiency, Per Cent: Less than 17-inch Diameter	Beam Efficiency, Per Cent: 17-inch Diameter and over
1	10 to less than 18	32	35
2	18 to less than 29	34	40
3	29 to less than 46	40	43
4	46 to less than 70	43	47
5	70 to less than 100	50	55

General Purpose Enclosed Floodlights — Class GP

Type	Beam Spread, Degrees	Beam Efficiency, Per Cent*: Less than 17-inch Diameter	Beam Efficiency, Per Cent*: 17-inch Diameter and over
1	10 to less than 18	34	35
2	18 to less than 29	36	36
3	29 to less than 46	39	45
4	46 to less than 70	42	50
5	70 to less than 100	46	50

Open Type Floodlights

Type	Beam Spread, Degrees	Beam Efficiency, Per Cent* (Less Insert) Class O	Beam Efficiency, Per Cent* (With Insert) Class OI
4	46 to less than 70		35
5	70 to less than 100		40
6	100 and up	55	60

*Refer to NEMA Standards FL 6-210 and FL 6-200.

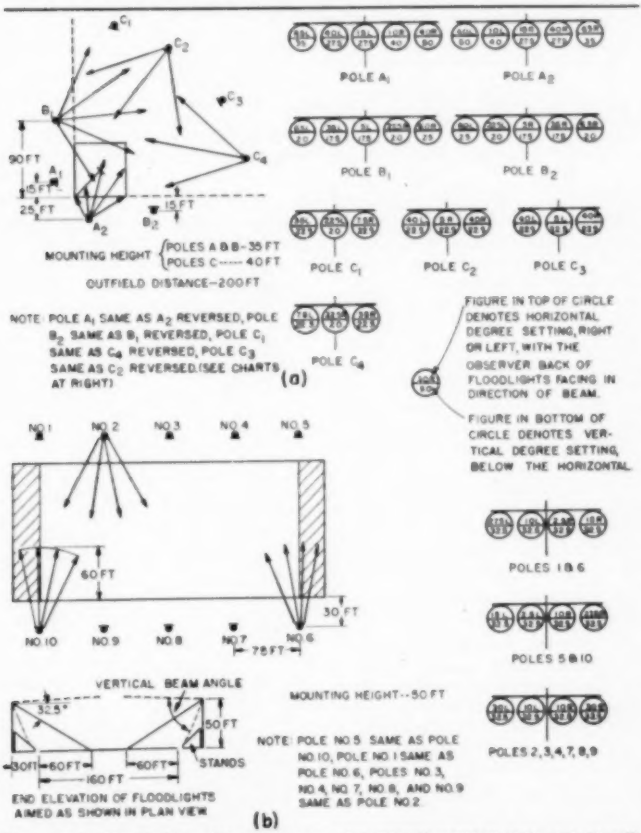

POLE A1
POLE A2
POLE B1
POLE B2
POLE C1
POLE C2
POLE C3
POLE C4
90 FT
15 FT
25 FT
MOUNTING HEIGHT {POLES A & B—35 FT / POLES C—40 FT
OUTFIELD DISTANCE—200 FT
NOTE: POLE A1 SAME AS A2 REVERSED, POLE B2 SAME AS B1 REVERSED, POLE C1 SAME AS C4 REVERSED, POLE C3 SAME AS C2 REVERSED (SEE CHARTS AT RIGHT)
(a)
FIGURE IN TOP OF CIRCLE DENOTES HORIZONTAL DEGREE SETTING, RIGHT OR LEFT, WITH THE OBSERVER BACK OF FLOODLIGHTS FACING IN DIRECTION OF BEAM.
FIGURE IN BOTTOM OF CIRCLE DENOTES VERTICAL DEGREE SETTING, BELOW THE HORIZONTAL.
NO. 1
NO. 2
NO. 3
NO. 4
NO. 5
60 FT
30 FT
78 FT
NO. 10
NO. 9
NO. 8
NO. 7
NO. 6
POLES 1 & 6
POLES 5 & 10
POLES 2, 3, 4, 7, 8, 9
VERTICAL BEAM ANGLE
32.5°
50 FT
30 FT
60 FT
60 FT
160 FT
STANDS
END ELEVATION OF FLOODLIGHTS AIMED AS SHOWN IN PLAN VIEW
MOUNTING HEIGHT—50 FT
NOTE: POLE NO. 5 SAME AS POLE NO. 10, POLE NO. 1 SAME AS POLE NO. 6, POLES NO. 3, NO. 4, NO. 7, NO. 8, AND NO. 9 SAME AS POLE NO. 2.
(b)

Figure B-1. Floodlight spotting diagrams: (a) 32-unit softball field, (b) 40-unit football field. Each unit indicates one floodlight beam; center of beam should strike ground at end of arrowhead.

Appendix B — Aiming of Floodlights

B-1—*General*—(a) In any sportslighting project, proper aiming of the luminaires upon installation is vitally important in order that the user may secure the full benefits of the quality that the manufacturer has built into his equipment and of the layout that the engineer has provided. In certain sports employing a symmetric field, such as football, the development of an aiming or "spotting" pattern is relatively simple, requiring merely that scale drawings be made showing the field and the floodlight beam spread angles. From an end elevation view, the vertical aiming of the floodlight beam axes may be determined to obtain approximately uniform horizontal illumination across the field together with sufficient "spill," "direct filament," or "beam-edge light" in the space above to provide uniformity to a height of 40 to 50 feet above the field. In this connection, care must be taken to minimize the amount of light from the upper portion of the floodlight beams falling in the opposite spectator stands. The plan view of the field makes it possible to plan horizontal aiming of the floodlights to provide approximately uniform horizontal illumination in the longitudinal direction of the field. Rigorous calculation methods make it possible to predetermine accurately the footcandle distribution provided by any given aiming pattern, but because such calculations are tedious, it is general practice to base spotting or aiming diagrams on previous calculations and practical experience with similar fields.

(b) Figure B-1b shows an end elevation view of the vertical beam coverage of two typical symmetrical beam floodlights aimed at a football field. It will be noted in this case that relatively wide beam floodlights (Type 5) are used because the poles are close to the playing field. It will be noted also that the upper parts of the beams of the two sets of floodlights indicated fall in the opposite stands. However, since these are the wide beam type, the candlepower in these upper portions will be low, and the spill brightness from them will be within comfortable limits when evaluated with respect to the relatively high brightness of the field itself.

(c) Typical aiming diagrams for football and softball are shown in Figure B-1. For minor sports where relatively few floodlights are employed aiming may be accomplished on the job by using these diagrams as a guide and following the basic principles discussed above. For more complex installations involving a larger number of floodlights it is desir-

able to obtain an aiming diagram in advance from the manufacturer of the lighting equipment.

B-2—***Field Methods of Adjusting Floodlights***—(a) There are several ways to put spotting or aiming information to use in making an installation. First and most accurate is manual aiming of the floodlight beam centers at predetermined spots on the playing area. This may be accomplished by using built-in beam sights or by placing accessory beam sights against floodlights parallel to their optical axes. Markers then are placed at the aiming points on the field and the sights aimed at those points.

(b) A second aiming method for directing the floodlights is to calculate or determine graphically from the aiming diagram the vertical and horizontal setting of each floodlight. Most floodlights are equipped with degree scales which may then be set to those angles. The accuracy of this method may be less than that of the one described above unless the poles are set accurately and the crossarms carefully leveled and aligned. A difference of only a few degrees may move the beam center 20 feet or more on the field.

(c) A third aiming method which may be used successfully with practice is to stand an observer on the field short of the aiming point (so the line from the floodlight to the aiming point passes approximately through the observer's eyes) to observe the floodlight, preferably through binoculars. As the floodlight is moved by an assistant, the observer then estimates the position in which the lamp filament (or concentric reflector rings) appears exactly centered in the floodlight aperture. An alternate observation method that may be used with the narrow-beam type (specular reflector) floodlight is to light the lamp and, with smoked glasses on (preferably with binoculars), estimate when the entire reflector appears uniformly bright and at a maximum brightness. The latter methods are inherently less accurate than the first method but may be satisfactory when relatively large numbers of medium or wide beam floodlights are directed into the same general area.

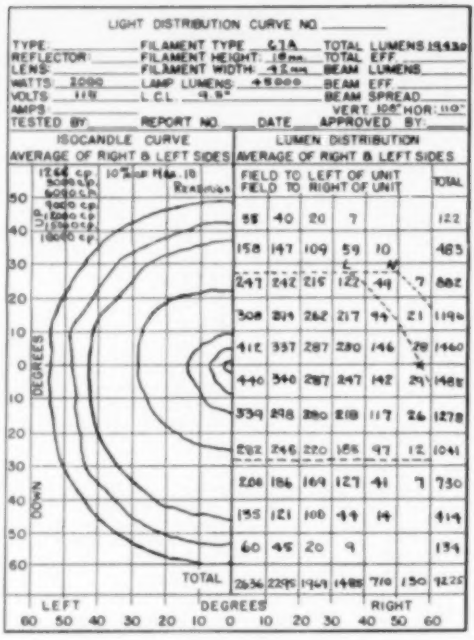


Figure D-1. Floodlight distribution data sheet.

Appendix C — Maintenance

C-1—*The Importance of Proper Maintenance*

Loss of illumination will result from the use of depreciated lamps and from accumulated dust and dirt on the reflecting or transmitting surface of any lighting luminaire whether installed outdoors or indoors. If the installation is indoors the resultant maintained illumination value is also affected by the condition of the ceiling, walls, and general surroundings. Depreciation of 25 to 50 per cent may be expected depending upon the efficiency of the maintenance program.

C-2—*Maintenance Factors for Outdoor Design Calculations*

In the design of a lighting installation calculated to provide specific illumination values using a given quantity of luminaires, it is necessary to assume specific maintenance factors as well as minimum efficiencies. For the basis of lighting design, it is recommended that the NEMA Standards[7] be applied to luminaire designation to permit the use of standard maintenance factors of 75 per cent of initial value for enclosed luminaires and 65 per cent for open luminaires.

C-3—*Maintenance Factors for Indoor Design Calculations*

For interior lighting calculations the maintenance factor used will depend upon the design of the specific luminaire chosen. For suggested maintenance factors for typical luminaires refer to Table 9-2 of the *I.E.S. Lighting Handbook*, Second Edition.[8]

C-4—*Frequency of Cleaning*

Since accumulation of foreign matter upon a luminaire depends upon the local atmospheric conditions, it follows that the frequency of cleaning the equipment must be determined on the basis of the existing atmospheric conditions and the type of lighting system employed. It is recommended that floodlight luminaires or industrial type luminaires used out-of-doors be thoroughly cleaned as follows:

(1) At the beginning of each season.
(2) Whenever a lamp is replaced.
(3) In extreme smoky areas at least once and preferably two or three times during the season.

For interior lighting systems a suitable cleaning schedule should be established by a check of the illumination periodically with a light meter. When the illumination has decreased to 75 per cent of its initial value the equipment should be washed. A thorough washing of interior lighting equipment at least twice a year is justified in most locations. In dirtier areas, three or four cleanings per year are needed to achieve the lowest cost operation in terms of footcandle-hours per dollar.

The frequency of cleaning the surrounds such as walls and ceilings is determined to a large extent by the amount and character of dirt contained in the atmosphere. Regular inspection and adequate cleaning are recommended to maintain the reflective efficiency and brightness ratios between luminaires and surrounds.

C-5—*Lamp Replacement*

(a) Replacement of lamps which are badly blackened and those which have reached approximately three-quarters of life expectancy is important in maintaining the continuity of the lighting.

(b) "Group replacement" of all lamps in an installation may be made at the time of the annual inspection and cleaning or when the lamps have burned approximately three-quarters of their average life expectancy. Group replacement minimizes outages during the playing season and removes from service lamps which have depreciated substantially. The lamps removed are inspected visually and the better ones saved for replacement at burnouts prior to the next group replacement.

C-6—*Cleaning Agents*

Neutral soap or neutral detergents completely dissolved in water, or mild cleaning agents will generally clean lighting equipment satisfactorily. Special cleaners are available for extremely dirty equipment.

C-7—*Physical Inspection*

Every time a luminaire is cleaned or relamped, it should also be inspected for mechanical defects. Prompt correction of any defects will serve to prolong the life of the equipment and minimize frequency of cleaning. Service men should be instructed to exercise reasonable care in handling lighting equipment, especially in not forcing shut the cover glass doors or globes when incorrectly aligned.

Appendix D — Calculation Method For Average Horizontal Footcandles

D-1—*Introduction*

(a) The method of calculating the footcandle level which can be expected from any given number and arrangement of floodlights or of calculating the number of floodlights required to produce a given level is more complicated than the interior lighting calculation. This is true because there are many variable factors such as the distance from the playing area to the floodlights, the mounting height, and the aiming of the floodlights.

(b) Some approximate methods of calculation have been developed and are available from the manufacturers of lighting equipment.[9, 10] The most accurate method of calculating the footcandles produced by a floodlight installation is one which was developed by NEMA and which is reproduced below. This method involves the use of light distribution curves of the isocandle type on which the area to be lighted is plotted around the beam axis.

(c) For calculation purposes, depending upon the accuracy required, one or more representative floodlight beam patterns should be chosen for each pole location where varying utilizations may result.

(d) The method of computation consists of plotting the area to be lighted on the photometric curve and then adding up the number of lumens contained inside the area. The number of lumens divided by the area in square feet gives the average illumination from the unit in footcandles.

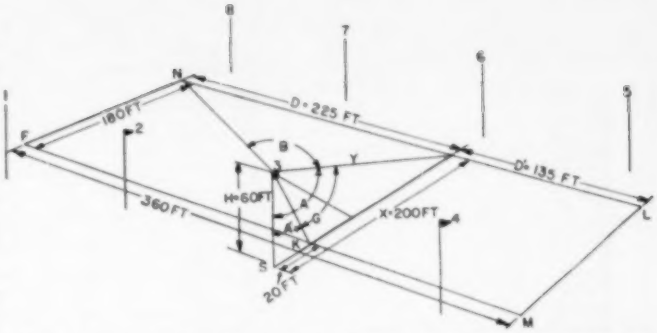


Figure D-2. Typical floodlighted football field used in sample calculation of average horizontal footcandles.

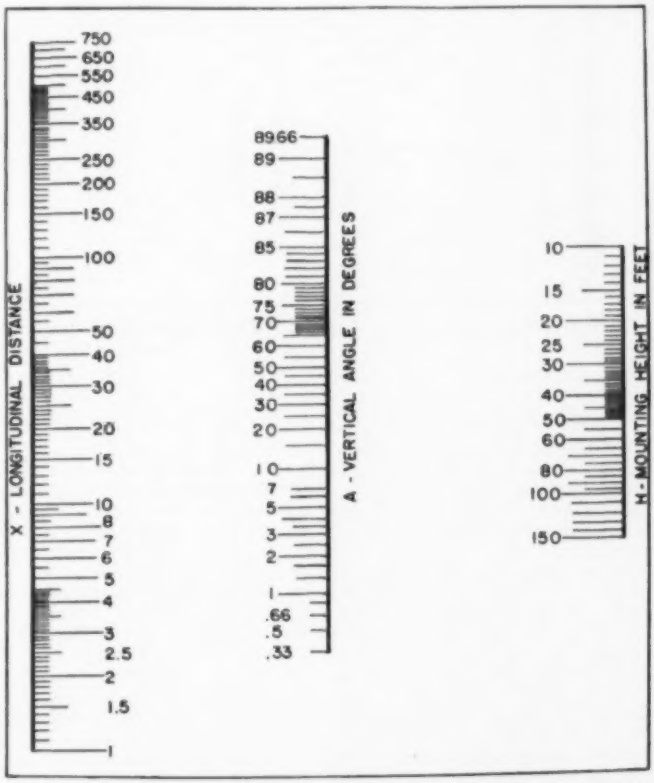


Figure D-3. Nomogram for determining vertical angle (angle *A* in Figure D-2) in terms of longitudinal distance *X* and mounting height *H*.

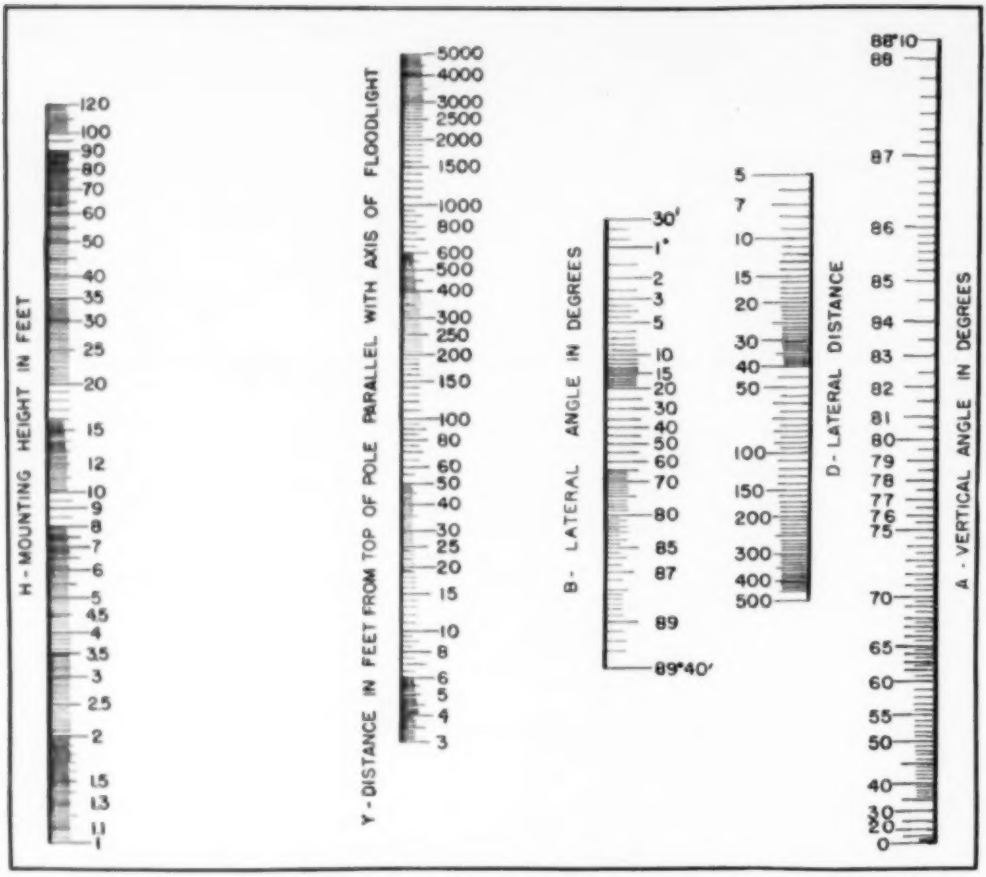


Figure D-4. Nomogram for determining lateral angle *B* in terms of vertical angle *A*, mounting height *H*, and distances *Y* and *D*.

D-2—*Sample Computation*

(a) An example of a typical area to be lighted is given in Figure D-2. The problem is to obtain the outline of the area in terms of lateral and vertical degrees and transfer it to the isocandle curve (Figure D-1).

(b) To simplify the problem, the floodlight is assumed to be projecting the light straight across the area; i.e.: a vertical plane through its center axis is perpendicular to the line *FKM* in Figure D-2. The two sides of the area *NL* and *FM* will appear on the isocandle curve as straight lines parallel to the horizontal beam axis. It is, therefore, necessary to calculate only the vertical angles *A* from the pole to the near and far sides of the area in order to draw them on the diagram. The extremities of these lines, or points *F*, *M*, *L* and *N*, must be found by obtaining the true lateral angle *B* in the plane passing through the floodlight and the side of the field in which the point is located. The contour of the side *FN* or *ML* is found by assuming a number of points on the line and finding the corresponding lateral and vertical angles. The vertical angles (*A*) are found from the nomogram, Figure D-3. The lateral angles (*B*) are found from Figure D-4. The exact procedure is as follows:

1. Refer to Figure D-3. Lay a straight edge across the chart connecting the distance *X* (200 feet) with the mounting height *H* (60 feet). On the center line *A* read the vertical angle *A* from the pole to the ray of light reaching the far side of the field (73.5 degrees). In the same way using *H* = 60 feet and *X* = 20 feet the vertical angle (*A'*) to the near side of the field is found to be 18 degrees.

2. Refer to Figure D-1. The location of the area on the chart depends on the angle at which the floodlight is tilted. The total vertical angle intercepted by the field is angle *G*, or angle *A* to the far side minus angle *A'* to the near side. This equals 73.5 — 18 or 55.5 degrees. For convenience, assume that the center axis of the floodlight is tilted to the point where it bisects this angle. Then the far side of the field is 55.5 degrees divided by 2 or 27.75 degrees above the axis, and the near side an equal number of degrees below. On the isocandle curve (Figure D-1) draw horizontal lines 27.75 degrees above and below the 0-degree axis.

3. To determine point *N*, refer to Figure D-4. Lay a straight edge across the chart from the mounting height $H = 60$ feet to the vertical angle $A = 73.5$ degrees and read on line *Y* (210 feet). Now connect 210 feet on line *Y* with $D = 225$ feet on line *D*, and read on line *B* the lateral angle (47.5 degrees). Plot this point on the top horizontal line. In the same way, find point *F* by using $A' = 18$ degrees and $D = 225$ feet. Points *L* and *M* are found using the same vertical angles as for *N* and *F*, respectively, and D' equals 135 feet.

4. The four corners of the area are now located, but the ends of the area will not appear as straight lines, so it is necessary to plot sufficient points to determine the curvature. The first points to be determined are those on the 0-degree center axis. The vertical angle to use on Figure D-4 is *A* minus 27.75 or 45.75 degrees. From this and $D = 225$ feet the point at the left is found to be 60 degrees, and from $D' = 135$ feet the point at the right is 56 degrees. At least one additional point above the axis and one below should be determined. These may be found by assuming vertical angles such as 15 degrees above the axis, or $A = (45.75 + 15) = 60.75$ degrees. With these points plotted on the isocandle curve the ends of the field can be drawn.

(c) With the field plotted on the curve, the lumens which fall on the field are added up. In the zones cut by the sides of the field, estimate the proportion of the lumens included within the boundary. A tabulation of these values is given below.

(d) Referring to Figure D-1, it will be noted that while the calculations have been made for a unit on pole 3, the same result applies to any unit on poles 2, 6 and 7. It is then necessary to make a similar calculation for pole 4, for instance, which result will also apply to any unit on poles 1, 5 and 8.

(e) It may happen that a better utilization factor and increased intensity can be obtained by tilting the floodlight at a different vertical angle. This can readily be determined by studying the summation of lumens in the lateral zones, given at the side of the isocandle curve. Tilting the beam up or down merely involves shifting the entire diagram of the field up or down the required number of degrees on the curve.

D-3—*Irregular Areas*

In the case of irregular areas the sides of the field, such as *FM* and *NL*, may not be straight lines or may not be parallel. In that case it will be necessary to determine both the vertical and lateral angles for several points on each line.

D-4—*Special Cases*

(a) In computing values for a closed projector installation where the projectors can be so located that all of the beams will fall on the area involved, the average initial intensity can be computed by dividing the sum of beam lumens of all of the floodlights by total area. In cases where the entire beam will not fall on the areas involved the method of computation described in Section D-2 should be used.

(b) For a baseball field installation where the average intensity for the infield is given, the computations should be made by the method given in Section D-2 or by the point-by-point method, selecting a sufficient number of stations within the area to give a true average. If values are required at specified points, the point-by-point method of computation should be used.

D-5—*Intensity at Various Points*

If further details on intensity at various points are desired, it is recommended that the so-called point-by-point method be used in computing illumination values. In view of the lengthy process and its well known principle, it is not included in this discussion.

Summation of Lumens on Field

Vertical Zones		Lateral Zones					
	From	0	10	20	30	40	50
	To	10	20	30	40	50	60
		Field to Right of Unit					
20 - 30		192	187	167	78	4	
10 - 20	Above	308	294	262	217	70	
0 - 10		412	337	287	250	146	10
0 - 10		440	340	287	247	143	26
10 - 20	Below	339	296	280	218	117	26
20 - 30		219	190	171	143	75	9
		Field to Left of Unit					
20 - 30		192	187	167	94	27	1
10 - 20	Above	308	294	262	217	94	19
0 - 10		412	337	287	250	146	28
0 - 10		440	340	287	247	143	29
10 - 20	Below	339	296	280	218	117	26
20 - 30		219	190	171	143	75	9
		3820	3292	2908	2320	1165	183

13,688 Total Lumens

Appendix E — Power Supply and Distribution for Floodlighting Installations

The electric utility serving the sports lighting project should be consulted as to the type and rates for service available, as well as rules for use of this service before plans are developed for the wiring.

In many communities the installation of wiring is governed by local ordinances based on the National Electric Code,[11] in other communities provisions of the code might well be followed because the merits of the Code are indicated by its wide spread acceptance.

Wiring plans will normally be prepared by the electrical engineer, after consultation with the electric utility, giving due consideration to the various factors involved such as service voltage, line voltage drop, and voltage rating of the lamps. These factors must be given consideration in order to secure the most effective use of the complete installation.

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12. Little, W. F.: "Practical Hints on the Use of Portable Photometers," *Trans. I.E.S.*, Vol. X, p. 766 (November 1915).

13. Buck, G. B.: "The Correction of Light Sensitive Cells for Angle of Incidence and Spectral Quality of Light," ILLUMINATING ENGINEERING, Vol. XLIV, No. 5 (May 1949).

Questions and Answers on light sources

The I.E.S. Committee on Light Sources, under the chairmanship of E. H. Raddin, has prepared this listing of answers to frequently-asked questions. Readers are invited by the Committee to submit similar questions of general interest on light sources, to be considered for publication from time to time. Questions may be sent in care of Society Headquarters.

If a lead-lag instant-start ballast fails in a fixture, may it be replaced with one of the new sequence-start ballasts?

Yes, providing the wiring of the fixture is changed as per instructions on the ballast. The wiring diagram on the sequence-start ballast must be followed carefully since this wiring is more complex than lead-lag wiring.

The lead-lag instant-start ballast has the neutral of the line connected to both of the stationary sockets of the two lamps, and it does not matter to which spring socket the output leads of the ballast are connected.

In the case of the sequence-start ballast, the neutral line is connected to the stationary socket of one lamp and the "hot" line is connected to the stationary socket of the second lamp. It is also extremely important that the output leads from the ballast be connected to the proper spring sockets as designated on the ballast. If these output leads are interchanged on the two lamps, poor starting and improper operation will result.

How does an "enlarger" bulb differ from a household lamp of the same wattage?

The enlarger bulb is made with a special diffusing surface to provide more uniform illumination. The manufacturer's etching is located on the neck instead of the end of the bulb so that the etch will not be imaged on the paper holder as might happen if a standard lamp were used. Also, the enlarger lamp has higher brightness and shorter life than the household lamp.

What is the principal factor that determines the construction of an incandescent filament lamp with respect to whether it is to be vacuum or gas-filled?

Generally speaking, the diameter of the filament wire is the determining factor. The filaments of the early incandescent lamp types were operated in evacuated glass bulbs, the purpose being to exclude air and thus keep the filaments from burning up. Later it was discovered that pressure exerted on the filament by an inert gas inside the bulb retarded the evaporation of the tungsten filament, thereby making it possible to design lamps for higher filament temperatures without reducing the life. Use of gas, however, introduces energy losses due to cooling effect of conduction and convection. The smaller the diameter of the wire, the greater the cooling effect, with the result that if the wire is too fine, the heat losses overcome the advantages of using gas. Wire with a current rating of less than about one-third ampere has a wire diameter so small that the use of a gas is a disadvantage rather than an advantage. For this reason, standard voltage, general lighting service lamps of less than 40 watts are of a vacuum or "Type B" construction while lamps of 40 watts and higher are gas-filled or "Type C."

What are considered the most effective sources for narrow beam projection systems?

The most effective sources are those with small size and high brightness, such as crater type carbon arcs and incandescent filament lamps having concentrated monoplane or biplane filament construction.

What are the principal gases used in incandescent filament lamps?

Most present day lamps have a mixture of argon and nitrogen in various proportions depending on the wattage and designed service. Use of argon results in a more efficient lamp but argon increases the tendency to ionize and cause an arc to develop between the lead-in wires. As the wattage or voltage or filament concentration increases, there is an increased tendency for a lamp to arc. Consequently with such increases, there is a decrease in the percentage of argon used in the fill gas. For example, the highly concentrated filament found in projection lamps necessitates the use of 100 per cent nitrogen gas. Krypton, a relatively rare and expensive gas, is most efficient but is only used in special types of lamps such as the small miner's cap lamp where highest efficiency is desirable throughout the life of the miner's battery. Hydrogen, very inefficient for general lighting lamps, is useful for signalling lamps since its rapid cooling effect on the filament produces quick flashing.

TELECAST

LIGHTING NEWS OF CURRENT INTEREST

March 1 Is Deadline for 1952 Conference Papers

The I.E.S. Papers Committee announces that a deadline date of March 1, 1952 has been established for the receipt from authors of outlines of their proposed papers for the 1952 National Technical Conference papers. It is realized that there are many excellent papers which could be written for this conference and authors are invited to submit their proposals.

Triplicate copies of the outlines should be mailed by March 1, 1952 to R. M. Zabel, Co-Chairman, Papers Committee, % Westinghouse Electric Corp., Lamp Division, Bloomfield, N. J.

If a prospective author receives tentative approval of the outline of his proposed paper, he must mail his manuscript to Mr. Zabel at the above address by May 1, 1952. It is the policy of the Papers Committee that no paper will appear on the program unless the manuscript has been approved by the Papers Committee.

Co-Chairmen of the 1952 Papers Committee are: L. E. Barbrow, Roy A. Palmer, and R. M. Zabel.

Committee Personnel Listings To Be Published in March

Numerous additional committee appointments were made at the Executive Committee meeting held January 10, and the Council meeting February 14. All of these additions will be incorporated in the new up-to-date listing of Committee Personnel to be published in the March issue of ILLUMINATING ENGINEERING.

Photography of Installations Subject of I.E.S. Program

A subject of very wide interest, but one seldom presented, was the basis of a recent I.E.S. meeting of the Puget Sound Section. This was "Photography as a Tool in Lighting," presented by Fred E. Cooper, a lighting engineer with Westinghouse, Seattle.

The objective of the meeting was to arouse the members interest in personally taking photographs so as to have records of new work completed, to have a guide for more accurate work in relighting existing spaces, and to have promotional pictures to use with clients and customers.

In addition, while projecting a series of colored slides on to a screen which showed typical school, office, and outdoor lighting installations in the Pacific Northwest, Mr. Cooper demonstrated with a light meter how the brightness ratios, color contrasts and even footcandle levels could be measured with fair approximation from the photographs.

Several tools available for everyone's use were demonstrated and discussed. The Polaroid Land camera with a flashgun attachment, which permits immediate development of the picture right in the camera as soon as it is taken, was one of the most interesting. Also certain little "tricks" of photography for making time exposures to keep moving people from showing on the film, or cars going past from showing in a picture, were described to show how very easy personal photography can be.

The concluding item was the 36-minute Eastman Kodak sound and color motion picture entitled "Functional Photography in Industry" borrowed from the Camera Club Department in Rochester, New York.

Maryland Section Charter Approved

Petition was made to the Council Executive Committee meeting held in New York January 10, for a Section Charter, by members of the Baltimore Chapter. The petition, with full particulars, was submitted through Regional Vice President Paul Hildebrand.

Following discussion of the qualifications outlined in the petition of the Baltimore Chapter and its record of activity, action was taken to approve transfer to Section status, approving also the change of the name of the group to Maryland Section.

GUEST SPEAKER, Warren H. Edman, Line Material Co., at a meeting of the Southern California Section, holds a miniature street light standard presented to him by Program Chairman Roy Dahlin. Mr. Edman spoke on "Popular Aspects of Street Lighting." At far right is S. H. Simonsen, Section Chairman.

Montreal Section Presents Advanced Course in Lighting

In cooperation with McGill University, Department of University Extension, the Montreal Section, I.E.S., is currently giving an advanced course on "Lighting Fundamentals and Design." Course Director, L. R. McCowan, of The Canadian General Electric Co., has scheduled ten lectures, 1½ hours each.

Light Sources — January 15
Lighting Systems — January 22
Quantity and Quality — January 29
Fixture Evaluation — February 5
Lighting Design — February 12
School Lighting — February 19
Office Lighting — February 26
Industrial Lighting — March 4
Store Lighting — March 11
Special Lighting — March 18

Eastern Pennsylvania Acquires Section Status

Deep snow and generally bad weather postponed, from December 18 to December 28, the presentation of the charter of section-hood to the former Eastern Pennsylvania Chapter. This postponement in no way affected the enthusiasm of the meeting, held in Bethlehem, Pa.

President S. G. Hibben was there to present the charter to Frank E. Heins, Section Chairman. Miss Myrtle Fahsbender, Westinghouse Electric Corp., was guest speaker with the topic, "My Impressions of European Home Lighting." Since Charter Night was also Ladies Night, this theme was most appropriate.

A tour of the city to see the Christmas street lighting concluded the evening.

WINNERS of the Prize Problem Award, given by the Twin City Section, and their instructors are: seated, Lloyd Williams, Richard Acott, Eugene Freerks and John Damberg; standing, Richard Lenci and Walter Vivrett, instructor. Robert Carny, Norman Nagel and Frederick Koeper, other instructors of prize winners, are not in photo.

Prize Problem Awards Announced by Twin City Section

Winners of the Prize Problem Awards, given annually by the Twin City Section of I.E.S. for the architectural students at the University of Minnesota, were announced at the December meeting of the Section.

First and second awards consist of forty-five and forty dollars and student memberships and were given to Eugene Freerks and Richard Acott. Recipients of student awards were John Damberg, Richard Lenci and Lloyd Williams.

This year the problem was lighting a restaurant and bar. The winning design combined well-conceived arrangements of line and large area light sources, concealed spot lights and luminaires to form an interesting interior.

Electrical Distributors To Hold Convention in June

Hotel reservations are already being placed for the National Association of Electrical Distributors Convention scheduled for June 8 through 12 in Atlantic City. Convention headquarters will be at the Ambassador Hotel there.

Detailed lists of the entire week's program as well as reservation blanks, are available at 250 Madison Ave., New York 17, N. Y. Addresses by prominent industry leaders, and general discussions on important industry problems, will be features of the program.

PRESENTATION of Section Charter to the former Eastern Pennsylvania Chapter was made in Bethlehem, Pa. December 28. President S. G. Hibben hands the charter to Section Chairman Frank E. Heins. Myrtle Fahsbender, guest speaker at the evening meeting, looks on.

Explosion-Proof Chamber For Testing Electrical Devices

An explosion-proof test chamber for electrical and electronic devices is in use at Wright Air Development Center, where items under test are operated in a mixture of air and aviation gasoline. The ⅜-inch steel test chamber is designed to withstand pressure of 100 psi. Various conditions of altitude, explosive concentration, and temperature can be obtained during tests. If a device operates satisfactorily without causing an explosion, it can then be tested for internal explosion.

Residence Lighting Forums Gaining Momentum

Notices of very active and worthwhile programs put on by the Society's several Residence Lighting Forums, are being received at headquarters with increasing frequency. Full scale eight-meetings-a-year programs are under way in New York, Detroit, Atlanta and Knoxville. Interest is also developing in Chicago, Philadelphia and Miami.

In the Michigan Section, as in New York and some others, Forum members hold joint meetings with their parent Section, at least once a year. An especially successful joint meeting was held in December at the Detroit Yacht Club. Since residence lighting reaches the interest of wives as well as engineers, many ladies were among the 100 people attending. An illustrated talk on Recreation Room Lighting by Miss Mary Taepke of Detroit Edison formed the main program.

A festive note was added to the occasion by a dinner for 100, with a cocktail hour preceding it. Miss Taepke followed this up with slides on Christmas decorative lighting ideas, and interesting lighting accessories.

Attendance Analysis Of Industrial Clinic

An analysis of the attendance at the recent clinic on Lighting for Industrial Production and Safety, co-sponsored by the I.E.S. Chicago Section, the Chicago Association of Commerce and Industry and the Chicago Lighting Institute, has been made. Total attendance was 212, and the breakdown by representation is:

Industrial Plants—81—38.2 per cent.
Public Utility Companies—61—28.8 per cent.
Lighting Equipment (Fixtures and Sources—47—22.1 per cent.
Electrical Wholesalers and Contractors —16—7.5 per cent.
General (schools, consultants and publications)—7—3.3 per cent.

Engineers Urged to Clarify Technical Speeches and Writing

The long standing problem of how engineers can make themselves more readily understood both in speech and written word to their colleagues and the public, was officially considered at one of the recent sessions of the American Institute of Electrical Engineers winter convocation at the Hotel Statler, New York. Three educators from New York University told the men and women engi-

(*Continued on page* 10A)

LIGHTING CALENDAR

Society Events

March 13, 1952—Meeting of I.E.S. Council Executive Committee.

March 13-14, 1952—South Pacific Coast Regional Conference, Hotel Sir Francis Drake, San Francisco, Calif.

March 20-21, 1952—Pacific Northwest Regional Conference, Hotel Victoria, Vancouver, B. C.

March 31, 1952—Meeting of I.E.S. National Council, Edgewater Beach Hotel, Chicago, Ill.

April 6-8, 1952—Southwestern Regional Conference, Hotel Tulsa, Tulsa, Okla.

April 20-22, 1952—Southern Regional Conference, Hermitage Hotel, Nashville, Tenn.

April 30 - May 2, 1952—Canadian Regional Conference, Hotel General Brock, Niagara Falls.

May 5-6, 1952—Great Lakes Regional Conference, Statler Hotel, Cleveland, Ohio.

May 8, 1952—Meeting of I.E.S. Council Executive Committee.

May 21-23, 1952—East Central Regional Conference, Webster Hall Hotel, Pittsburgh, Pa.

June 18, 1952—Meeting of I.E.S. Council, New York, N. Y.

June 19-20, 1952—Northeastern Regional Conference, Hotel Preston, Swampscott, Mass.

July 10, 1952—Meeting of I.E.S. Council Executive Committee.

September 8-13, 1952—Illuminating Engineering Society, National Technical Conference, Edgewater Beach Hotel, Chicago, Ill.

Industry Events

March 3-6, 1952—Institute of Radio Engineers, Convention, Waldorf-Astoria Hotel & Grand Central Palace, New York City.

March 5-8, 1952—Essex Electrical League, Seventh Annual Electrical Industrial Exposition, Terrace Ballroom, Newark, N. J.

March 10-13, 1952—National Electrical Manufacturers Ass'n, Edgewater Beach Hotel, Chicago, Ill.

March 22 - April 6, 1952—Chicago International Trade Fair, Navy Pier, Chicago, Ill.

March 24-26, 1952—American Society Mechanical Engineers, Spring Meeting, Seattle, Wash.

March 26-28, 1952—American Power Conference, Hotel Sherman, Chicago, Ill.

April 1-3, 1952—Edison Electric Institute, Sales Conference, Chicago, Ill.

April 1-4, 1952—Greater New York Safety Council, 22nd Annual Safety Convention & Exposition, Hotel Statler, New York City.

April 28-30, 1952—Canadian Electrical Distributors Association, General Brock Hotel, Niagara Falls, Ont.

April 28 - May 3, 1952—Chamber of Commerce, Annual Meeting, Washington, D. C.

May 4-8, 1952—The Electrochemical Society, Inc., National Convention, Benjamin Franklin Hotel, Philadelphia, Pa.

May 5-7, 1952—Engineering Institute of Canada, 1952 Annual Meeting, Hotel Vancouver, Vancouver, B. C.

May 5-9, 1952—33rd Annual National Restaurant Association, Convention & Exposition, Navy Pier, Chicago, Ill.

May 6-9, 1952—Fourth International Lighting Exposition & Conference, Cleveland Municipal Auditorium, Cleveland, Ohio.

May 8-9, 1952—Public Utilities Advertising Association, Annual Convention, Hotel Radisson, Minneapolis, Minn.

May 12-13, 1952—Electrical Contractors Association of Ontario, Annual General Meeting, General Brock Hotel, Niagara Falls, Ont.

June 2-5, 1952—Edison Electric Institute, 20th Annual Convention, Cleveland, Ohio.

June 8-21, 1952—International Organization for Standardization (ISO), General Assembly, Council and a Number of Technical Committees, Columbia University, New York, N. Y.

Week of June 9, 1952—44th Annual Convention, National Association of Electrical Distributors, Atlantic City, N. J.

June 23-27, 1952—Summer General Meeting, American Institute of Electrical Engineers, Hotel Nicollet, Minneapolis, Minn.

Week of June 23, 1952—American Society for Testing Materials, 50th Anniversary Meeting, Hotels Statler and New Yorker, New York, N. Y.

June 30 - July 2, 1952—Canadian Electrical Association, Annual Convention, Banff Springs Hotel, Banff, Alta.

August 19-22, 1952—Pacific General Meeting, American Institute of Electrical Engineers, Phoenix, Ariz.

September 8-10, 1952—American Standards Association's Third National Standardization Conference, Museum of Science and Industry, Chicago, Ill.

September 8-11, 1952—Institute of Traffic Engineers, Annual Meeting, Hotel Sherman, Chicago, Ill.

October 1-3, 1952—Canadian Electrical Manufacturers Association, 8th Annual Meeting, General Brock Hotel, Niagara Falls, Ontario.

October 7-9, 1952—Pacific Coast Regional Restaurant Convention and Exposition, Biltmore Hotel, Los Angeles, Calif.

October 13-17, 1952—Fall General Meeting, American Institute of Electrical Engineers, New Orleans, La.

October 20-24, 1952—40th National Safety Congress & Exposition of the National Safety Council, Chicago, Ill.

November 10-13, 1952—National Electrical Manufacturers Association, Haddon Hall Hotel, Atlantic City, N. J.

January 19-23, 1953—Winter General Meeting, American Institute of Electrical Engineers, New York, N. Y.

March 9-13, 1953—National Electrical Manufacturers Association, Edgewater Beach Hotel, Chicago, Ill.

Week of May 24, 1953—45th Annual Convention, National Association of Electrical Distributors, Stevens Hotel, Chicago, Ill.

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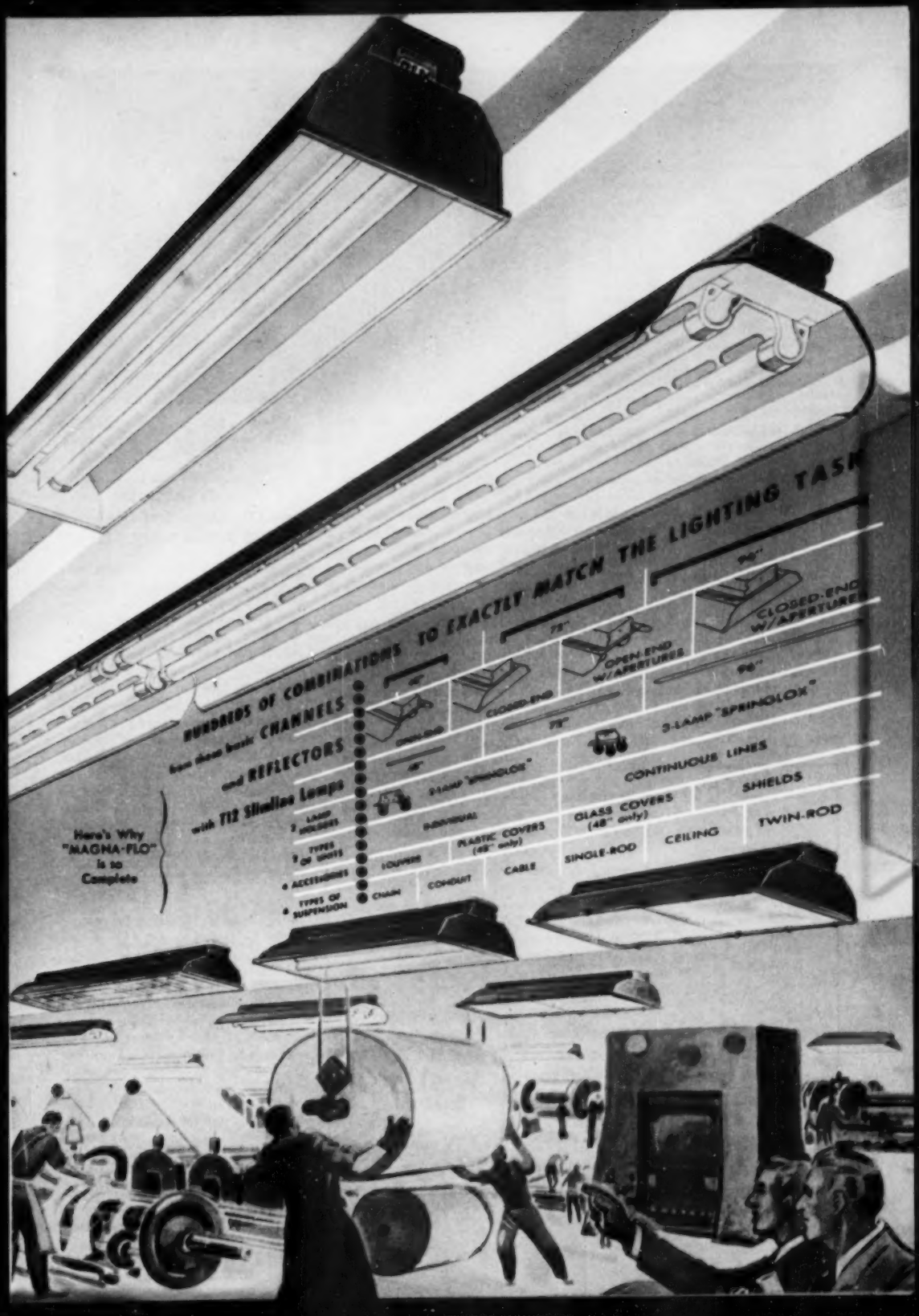
so complete, you can always obtain Task Matched Lighting Installations

To get all the extra lighting efficiency of the three new T12 Slimline Lamps, you need units that are MATCHED TO THE TASK—not substitute sizes and types, or a compromise on a "second choice." You get MATCHED TO THE TASK Units when you specify Benjamin "Magna-Flo" Fluorescent Lighting Units!

Like all Benjamin Lighting Systems, the "Magna-Flo" Line is complete! It is *so complete* because, basically, just three channel sizes and four types of reflectors form the backbone of an almost unlimited system to match any industrial lighting task!

High bays or low ceilings, moist or dirty locations, assembly lines or drafting tables, continuous-line lighting or individual units, lighting for inspection or mass production—whatever the seeing conditions and requirements of the task, you can get a "Magna-Flo" System that is MATCHED TO THE TASK because it is *so complete!* Further, in "Magna-Flo" Systems you get the most important features for sustained lighting performance and simplified maintenance, including exclusive Benjamin "Springlox" Lampholders for "easy-in, easy-out" lamp maintenance.

Write for Bulletin AD-5705 for complete specification data on Benjamin "Magna-Flo." Benjamin Electric Mfg. Co., Des Plaines, Ill. Dept. I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Here's Why "MAGNA-FLO" is so Complete
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(Continued from page 7A)

neers how they could clarify and not mystify when they speak or write technical papers.

Ormond J. Drake, Assistant Dean and Chairman of the Department of Speech and Dramatics of New York University College of Arts and Pure Science, and Prof. George R. Sargent told the meeting how to "Humanize the Technical Speech"; E. J. McAdam, Jr., Professor of English at the same college, spoke on "Writing Visually." The session was titled, "The Mechanism of Communications." Dean Drake said he used the word "humanizing" with "cruel and deliberate intent" because "most technical speeches are not human."

Prof. Sargent admonished speakers on technical subjects to clarify and not mystify, not to try to tell too much and to give their listeners "a map." Referring to the "map" he said: "When we take an automobile trip, we like to know where we are going and how we are going to get there. . . . The technical speech is not to be treated as a murder mystery so don't be afraid to tell your listener what you intend to do." A third way to humanize a technical speech, he said, is to arrange "your ideas so that the listener sees his relation to your subject early in the speech." He also urged that language be kept as simple as accuracy permits and to make it conversational.

Prof. McAdam advised his audience to keep in mind the type of person who was to read a projected paper and not to talk down to him.

"But don't over estimate his information," he warned.

The use of homely, easily understood analogies to give a picture of what you are writing about, Prof. McAdam said, and quoted several newspaper science writers who have used this method to clarify difficult subjects.

Using visual images and writing with imagination means work, he said, "But you will find it a change from the kind of writing you do for the technical journals, perhaps, and it can be stimulating to you. It may take some of the drudgery out of writing. And you have no idea how grateful your public will be."

VISITORS to Minneapolis, the Winnipeg Chapter, I.E.S., were entertained by the Twin City Section. Hosts and guests are here shown at dinner meeting.

I.E.S. Regional Conferences, 1952

South Pacific Coast	Sir Francis Drake Hotel San Francisco, Calif.	March 13-14
Pacific Northwest	Hotel Victoria Vancouver, B. C.	March 20-21
Southwestern	Hotel Tulsa Tulsa, Okla.	April 6-8
Southern	Hermitage Hotel Nashville, Tenn.	April 20-22
Canadian	General Brock Hotel Niagara Falls, Ont.	April 30 - May 2
Great Lakes	Statler Hotel Cleveland, Ohio	May 5-6
East Central	Webster Hall Hotel Pittsburgh, Pa.	May 21-23
Northeastern	Hotel Preston Swampscott, Mass.	June 19-20

Twin City Section Entertains Winnipeg Chapter

The Twin City Section of I.E.S. were hosts at a joint meeting with the Winnipeg Chapter. Twenty-five members of the Winnipeg Chapter, headed by T. W. Birt, journeyed to Minneapolis to join in the festivities. A tour of inspection of outstanding lighting installations was held during the day.

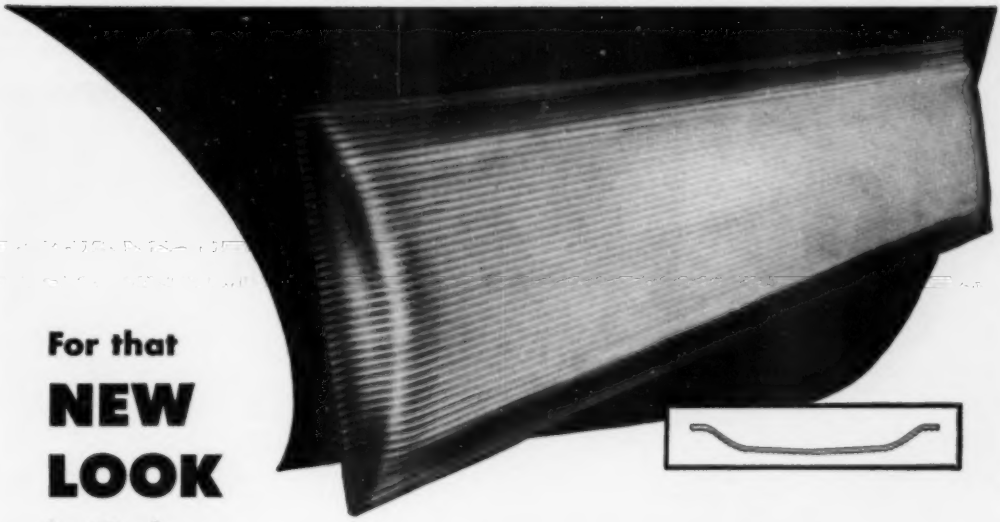
Main speaker at the evening meeting was R. G. Slauer, manager of the application laboratory, Sylvania Electric Products, Inc., who spoke on electroluminescence.

Ending the two-day activity the Canadian visitors had a chance to compare American college football with their their national version when they formed a loud cheering section at the Minnesota-Indiana game.

Young Engineer Training Program To Be Sponsored by E.C.P.D.

An organized program to aid young engineers in the first five years of professional development through the medium of a network of local committees made up of established practicing engineers is being sponsored by the Training Committee of Engineers' Council for Professional Development. Under the chairmanship of A. C. Monteith, Vice President in charge of Engineering and Research, Westinghouse Electric Corp., Pittsburgh, Pa., the Training Committee presented a 6-point

(Continued on page 13A)



For that NEW LOOK in Modern Interior Styling

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New curved panels of popular ALBA-LITE enhance the clean-lined styling of modern interiors. Their long lengths minimize the number of visible joints in continuous runs—give rooms that smooth new look and freshness.

Made in open and closed end pieces in lengths up to 48", they are adapted to standard fixture construction of both the hinged door frame and continuous open trough types. Unlike other materials, ALBA-LITE will not sag, warp, discolor or scratch. Maintenance costs are minimized... cleaning is a matter of seconds.

The soft opal glass in these new panels diffuses light evenly throughout the room, providing fixtures with controlled brightness and a pleasing appearance both when lighted and when not in use.

Curved ALBA-LITE panels are available through all leading fixture manufacturers, many of whom feature ALBA-LITE in their fixtures. If you are seeking new treatments or new solutions to standard lighting problems, send for Bulletin LS-32 and a set of Photometric sheets describing ALBA-LITE and other Corning engineered lightingware. They are yours for the asking.

ALBA-LITE is also available in 3 standard patterns in flat sizes up to 24" x 100", or bent to your particular specifications. It is adaptable to any type installation where color fidelity, high light efficiency, and maximum design flexibility are needed. It is ideally suited for totally direct lighting in luminous ceilings and recessed fixtures, or for semidirect lighting in suspended fixtures.

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Day-Brite Lighting Speeds Production...Reduces Spoilage

Every production man knows that good lighting often makes the difference between mediocre work slowly done and good work quickly done. But improving factory lighting means more than merely increasing the footcandles of light intensity . . . because too much light or glare can be as harmful as too little light. To get best results, *plant lighting must be both adequate and comfortable.*

That's why more and more plants, like the one shown above, are turning to Day-Brite to solve their lighting problems. In Day-Brite lighted plants, workers can see more clearly . . . without glare or shadows . . . and they do better work as a result. And plant management gets better production per man, higher employee morale, and far less spoilage.

This is important, too: Day-Brite lighted plants consistently have fewer accidents, far better safety records than generally found in less adequately lighted factories.

Today, hundreds of factories across the nation use only Day-Brite lighting fixtures . . . and get complete satisfaction. If *you* have factory lighting problems, Day-Brite will help you solve them, without obligation. Write to Day-Brite Lighting, Inc., 5432 Bulwer Ave., St. Louis 7, Missouri.

**The upward component provided through the reflector apertures minimizes contrast between the fixture and the surrounding ceiling area, adding to the over-all comfort of the complete installation.*

NOW MORE THAN EVER

AMERICA MUST SEE WHAT IT'S DOING

IT'S EASY TO SEE WHEN IT'S

"DECIDEDLY BETTER"
DAY-BRITE
Lighting Fixtures

216

(Continued from page 10A)

program to aid the young engineer in the right type of training, of indoctrination, and of self-analysis.

The program presented examples of orientation and in-service training, continued college education, introduction to community service, indoctrination in characteristics, responsibilities and ethics of the profession leading to recognition through registration, self-appraisal for the purpose of orienting personal plans and of selected reading for professional and personal growth.

To implement the program the committee proposed that an extension director be employed for the purpose of organizing the resources and agencies which might help in establishing programs in a number of chosen communities. Funds are presently being raised to initiate the program.

Six New Sustaining Members, I.E.S.

At the Council Executive meeting held in New York January 10, six new Sustaining Members were elected. The firms approved were:

Advance Electrical Supply Co.
2033 W. Madison
Chicago, Ill.
Official Representative: Lee Butler

Atlantic City Electric Co.
1600 Pacific Avenue
Atlantic City, N. J.
Official Representative: John B. Taylor

Fullerton Manufacturing Corp.
17 Chestnut Street
South Norwalk, Conn.
Official Representative: Lawson Fullerton

Harvstone Manufacturing Co.
542 E. 75th St.
Chicago 19, Ill.
Official Representative: A. M. Riskind

Markstone Manufacturing Co.
2460 W. George St.
Chicago, Ill.
Official Representative: Martin Schwartz

Mitchell Manufacturing Co., Ltd.
19 Waterman Ave.
Toronto 13, Ont., Canada.
Official Representative: J. E. Landers

I.L.E. Appoints Chairmen Of Regional Committees

Reports from Chairmen of the Regional Attendance Committees recently appointed indicate mounting interest in the 4th International Lighting Exposition and Conference, to be held May 6-9 at the Cleveland Auditorium. According to L. J. Rozier, Chairman of the Attendance Promotion & Publicity Committee, these Regional Committees are enthusiastically getting under way in 46 cities. Readers are urged to contact these committees for information on all phases of the Exposition and particularly attendance at the Exposition. Each Committee has a supply of Advance Registration Tickets which will give all those interested in attending an opportunity to arrange for their badges in advance and to avoid waiting in line. Chairmen appointed are as follows:

JOINT MEETING of the Carolinas Chapter, I.E.S. and the Carolinas Chapter, National Electrical Contractors Association featured Frances Armin of the Adequate Wiring Bureau as speaker. In the photo above are, left to right, Norman E. Tindal, Chairman, Carolinas Chapter of I.E.S.; Mrs. D. L. Casey; John C. Bolen, Governor of the N.E.C.A. Carolinas Chapter; Ralph K. Robinson, Treasurer of the N.E.C.A. Carolinas Chapter; Miss Frances Armin; Roy A. Palmer, Director of I.E.S.; Mrs. John C. Bolen; D. L. Casey, chapter manager for N.E.C.A.

SOUTHERN REGION

Atlanta, Georgia
Marshall L. Whitman, Wakefield Brass Co.
Birmingham, Alabama
H. W. Brown, Westinghouse Electric Corp.
Charlotte, North Carolina
Gordon Wells, Day-Brite Lighting, Inc.
Huntington, West Virginia
Charles Robison, Jr., Wakefield Brass Co.
Miami, Florida
Furna E. Lott, Wheeler Reflector Co.
Nashville, Tennessee
Joe W. Fowler, The Miller Co.
New Orleans, Louisiana
Hutson Colcock, Wheeler Reflector Co.

EASTERN REGION

Bloomfield, New Jersey
S. F. Hauser, Day-Brite Lighting, Inc.
Hartford, Connecticut
Joseph T. Osterby, Benjamin Elec. Mfg. Co.
Kenmore, New York
Herbert C. Zang, Electro Mfg. Corp.
Lancaster, Pennsylvania
Oscar Luttringer, Smithcraft Lighting Div.
Meriden, Connecticut
H. L. Harrison, The Miller Company
New York, New York
George Taylor, Day-Brite Lighting, Inc.
Pawtucket, Rhode Island
C. Inglis Wetmore, Electro Mfg. Corp.
Philadelphia, Pennsylvania
J. B. Derr, Electro Mfg. Corp.
Pittsburgh, Pennsylvania
George Kielty, Mitchell Mfg. Company
Rochester, New York
R. A. Siedle, Curtis Lighting, Inc.
Stratford, Connecticut
Frank E. Brown, Day-Brite Lighting, Inc.
Syracuse, New York
Frank N. Brown, Electro Mfg. Corp.
Washington, D. C.
Crawford Maddox, The Miller Company
West Reading, Pennsylvania
H. B. Elliott, Holophane Co., Inc.
Wilkes-Barre, Pennsylvania
Mitchell Davis, Swivelier Co., Inc.

MIDWESTERN REGION

Chicago, Illinois
Jas. R. Chambers, Benjamin Elec. Mfg. Co.
Cincinnati, Ohio
E. J. Wilson, Curtis Lighting, Inc.
Cleveland, Ohio
Paul R. Smith, Mitchell Mfg. Company
Columbus, Ohio
F. L. Lewis, The Miller Company
Des Moines, Iowa
James H. Hull, Jones Metal Products Co.
Detroit, Michigan
H. T. Dutter, Jr., Pittsburgh Reflector Co.
Indianapolis, Indiana
T. D. Wilson, Wakefield Brass Co.
Kansas City, Missouri
William B. Terry, Electro Mfg. Corp.
Milwaukee, Wisconsin
Earl H. Alk, Day-Brite Lighting, Inc.
Minneapolis, Minnesota
A. J. Fleming, Lighting Products, Inc.
Sandusky, Ohio
Arch Stevenson, Wakefield Brass Company

(Continued on page 14A)

(Continued from page 13A)

Springfield, Illinois
Howard Russell, Lighting Products, Inc.
St. Louis, Missouri
C. B. Mory, Garden City Plating & Mfg. Co.

WESTERN REGION

Dallas, Texas
Walter J. Huemmer, Lighting Products, Inc.
Denver, Colorado
C. D. Bolt & Co., Day-Brite Lighting, Inc.
Houston, Texas
N. O. Reed, Day-Brite Lighting, Inc.
Los Angeles, California
L. A. Hobbs, Smoot-Holman Company
Omaha, Nebraska
G. C. Mittauer & Assoc., Jones Metal Prod.
Phoenix, Arizona
Wm. Bennedorf, Smithcraft Lighting Div.
Portland, Oregon
Lee M. Baxter, Revere Electric Mfg. Co.
Salt Lake City, Utah
Mark Bryner, Day-Brite Lighting, Inc.
San Francisco, California
Matt A. Cabot, Day-Brite Lighting, Inc.
Spokane, Washington
Walter A. Tuly, Day-Brite Lighting, Inc.

CANADA

Toronto, Ontario
W. A. Dalrymple, Day-Brite Lighting, Inc.

I.E.S. National Technical Conferences

September 8-13, 1952 — Edgewater Beach Hotel, Chicago, Ill.

Week of September 14, 1953 — Hotel Commodore, New York, N. Y.

Week of September 12, 1954 — Chalfont-Haddon Hall, Atlantic City, N. J.

IT SEEMS TO ME

Noise Reduction Coefficients

To the Editor:

In the November 1951 issue of ILLUMINATING ENGINEERING, on page 567, there is an article on "Light and Sound Absorption" by T. D. Wakefield. In the text of the article, various absorption coefficients are given for an acoustical baffle, which is implied to be that manufactured by the F. W. Wakefield Brass Company, Vermilion, Ohio. The article states that the noise reduction coefficient is 0.90 whereas in Bulletin XIII of the Acoustical Materials Association, the noise reduction coefficient for this manufacturer's acoustical baffle is 0.30.

I would appreciate any comments you might have as to the explanation of this discrepancy. If the baffle referred to was not that manufactured by the author, he should so state in view of the above discrepancy. — D. G. PARKER, *Lighting Engineer, Columbia Electric and Manufacturing Co., Spokane, Wash.*

To the Editor:

Mr. Parker's question is a logical one. And we have a logical answer!

It comes about this way. The usual test panel at Riverbank Acoustical Laboratory covers 72 square feet of acoustical panels. Our baffles, in order to cover this area as normally installed, would take three eight-foot baffles. Since the baffles are six inches deep but extend on both sides, we have a square foot of absorption per foot of baffle, or 24 square feet. The absorption for the baffle is .90 per lineal foot of baffle, but if this absorption is spread over 72 square feet, we get only a third, namely 0.30.

This is a technical question which came up before the Technical Committee of the Acoustical Materials Association. There was much discussion pro and con as to how it should be listed. The Acoustical Materials Association is made up of members primarily manufacturing acoustical tile. A suspended acoustical baffle is quite new to them and its method of listing has caused a major revision for the next issue of the bulletin.

In our own publication "The Wakefield Ceiling," we list the coefficient of noise reduction two ways: (1) for the square foot of ceiling area and (2) per square foot of acoustical baffle. Thus you can see that either 0.30 or 0.90 is correct depending upon the area to which it is applied. — T. D. WAKEFIELD, *Vice-President, The F. W. Wakefield Brass Co., Vermilion, Ohio.*

GEORGIA Section members celebrated Christmas at an annual party held in the American Legion Restaurant in Atlanta. Attendance numbered over 100, due largely to the efforts of the party committee, headed by John T. Chambers, Georgia Power Co. Other members of the committee, shown holding some of the awards made at the party, included, left to right, Ernest Boynton, Electric Supply Co.; Walter C. Fink, Jr., Senior Fluorescent, Inc.; Clarence D. Holland, Electric Sales & Service Co., chairman of entertainment; Oren M. Ruff, Jr., Ruff & Cannon.

BOOKS AND PAMPHLETS

*Books whose reviews are marked * are available for inspection at Headquarters Office, Technical Department.*

***Introduction to Lighting** by Howard Sharp, published 1951 by Prentice-Hall, Inc., New York; 346 5½ x 8¼ inch pages, 207 illustrations, 70 tables; price $6.65.

This volume is an excellent "introduction to lighting" somewhat more simplified and easier to read. In the words of the author: "The approach is from the viewpoint of the practicing engineer. The underlying concepts are clearly developed and coordinated, using both simple mathematics and geometric solids to convey a physical impression of these concepts and, where applicable, the calculus as well, to prepare the student for more advanced

(Continued on page 16A)

HOW BALLASTS CONTRIBUTE

TO BETTER FLUORESCENT LIGHTING

"I help the lamp warm up to its job"
"The lamp gets a kick out of my magnetic personality"
Fluorescent Ballast Tells Her Story
GENERAL ELECTRIC

FREE! New G-E Book Tells "Flora's" Story

Meet a young lady you should get to know—Fluorescent Ballast ("Flora" for short). Says Flora:

"If you haven't met me before, that's because they keep me backstage out of sight and let the lamps take all the bows. I don't mind because, as you'll soon see, the lamps couldn't perform at all without my help.

"My name comes from what I do. My main job is to keep fluorescent light steady . . . on an even keel . . . something like the 'ballast' in a ship. I stabilize the flow of electricity through the lamp . . ."

And so Flora tells her story in simple, easy-to-understand language. In addition to explanations of fluorescent lighting itself, the booklet contains simple explanations of various ballast circuits and the advantages and disadvantages of each. From the simplest resistance ballasting to automatic starters, up through two-lamp ballasts, instant-starting lamps, series operation with sequence starting and, finally, trigger-start ballasts—all are carefully described.

To find out how good ballasts save you money, and why they are vital to fluorescent lighting, fill out the coupon and send it in. You'll receive your copy of "Fluorescent Ballast Tells Her Story" immediately.

General Electric Co., Sect. D 412-95,
Schenectady 5, New York

Gentlemen: Please send me FREE copy of your booklet, GEA-5731, "Fluorescent Ballast Tells Her Story."

Name .....

Company .....

Street .....

City ..... State .....

GENERAL ELECTRIC

(Continued from page 14A)

study. Well aware of the difficulty encountered by students in relating the basic mathematical concepts to actual application practice, the author has endeavored first to make the fundamentals clear, and then to emphasize constantly those fundamentals as they appear in application techniques. . . .

"The production, control, and measurement of light as a scientific tool is first explained, and then across the bridge of vision the application of light is developed into lighting. . . . The material is suitable for a formal college course, or portions of it may be utilized for industry training programs. Problems based upon actual situations are provided liberally, along with extensive luminaire photometric data."

Chapter headings include nomenclature; basic concepts; electric lamps; ballasts, transformers, and starters; control of light; luminaires; measurements of light and lighting; candlepower distribution curves; coefficients of utilization; principles of lighting design; vision; offices and schools; factories; stores; specialized techniques—floodlighting, cove lighting, and downlighting; and lighting cost analysis.

The author is a consulting engineer, Assistant Professor of Engineering at the University of Buffalo, and a Past President of the Illuminating Engineering Society.

Photometry and the Eye by W. D. Wright, published by Hatton Press, Ltd., London, 1949; 127 4¾ x 7¼ inch pages, 30 illustrations; price $2.00.

The six chapters of this book correspond to a series of six lectures given by the author at the Imperial College of Science and Technology in London. They include discussions of some of the most elementary as well as some of the more complex concepts in photometry. The author has made a special point of distinguishing between physical units and psychophysical relations. The material is presented in the author's usual analytical and comprehensible manner.

Topics treated include Photometric Procedure, the Luminosity Curve of the Eye, Heterochromatic Photometry, Photometry at Low Illuminations, the Photometry of Small Sources and the Photometry of Flashing Light Sources. This text should be very helpful to both the student and practitioner.

The Seventh Edition of the **National Electrical Code Handbook**, by Arthur L. Abbott published by the McGraw-Hill Book Co., 330 W. 42nd St., New York 18, N. Y., is available at a price of $6.00.

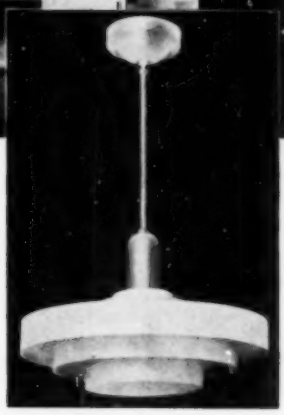
The Handbok is a systematic rearrangement of Code matter with detailed explanations of special problems and their applications. The first three sections take up (1) Definitions and General Provisions; (2) Approved Types of Wiring and Voltage Limitations; (3)

(Continued on page 18A)

Installations to See When You Visit Maine

Installation	Address	Interesting Feature
Dillingham & Sons	62 Spring, Auburn	Fluorescent and incandescent—cold cathode cove on dimmer.
St. Louis Church	Dunn St., New Auburn	Incandescent, direct and indirect. X-ray units.
First National Granite Bank	Augusta	Low brightness fluorescent.
Depositors Trust Co.	Augusta	Custom-built fluorescent.
State Highway Dept.	State House, Augusta	Indirect fluorescent.
Central Maine Power Co.	Augusta	Fluorescent and incandescent — louvered ceiling.
Bath Savings Institution	Bath	Fluorescent.
Grammar School	Bingham	Fluorescent 40-60 units.
Bowdoin College	Brunswick	Fluorescent.
Dover Motor Co.	Dover-Foxcroft	Fluorescent louvered units with luminous plastic sides.
Gardiner Schools	Gardiner	Fluorescent lighting in all schools.
Methodist Church	Gardiner	Fluorescent and incandescent — custom-built recessed panels.
Central Maine Power Co.	134 Main, Lewiston	Custom-built fluorescent and incandescent.
Paradis & LeBlanc	Lisbon St., Lewiston	Fluorescent with incandescent corner boxes.
Maine Central Institute	Pittsfield	Fluorescent louvers.
Poland Community Church	Poland	Recessed direct, cove and wall urn indirect—all on dimmers and silent switches. Three picture windows lighted from exterior.
Rockland South School	Rockland	Aluminum 2-lamp fluorescent troffers.
Central School	Thomaston	Fluorescent 40-60 units with low brightness T17 lamps.
Redington Furniture	Waterville	Recessed fluorescent.
Tardiff Jewelry	Waterville	Fluorescent lighting.
All grammar schools	South Portland	Fluorescent lighting and planned painting.
King Junior High	92 Deering, Portland	Fluorescent lighting in new school.
Ricker Bldg.	509 Forest, Portland	Fluorescent office lighting.
Eastland Hotel	157 High, Portland	Fluorescent 40-watt T17 low brightness lamps for office.
Chapman Arcade	477 Congress, Portland	Fluorescent skylighting.
First Free Baptist Church	873 Sawyer, S. Portland	Incandescent church lighting.
Cortell Segal Co.	23 Hammond, Bangor	Recessed incandescent and fluorescent wall case.
Allan Lewis Co.	181 Exchange, Bangor	Fluorescent and incandescent.
W. T. Grant Co.	6 Central, Bangor	Fluorescent and incandescent.
Schools	Bangor, N. E. Harbor, Brewer, Millinocket	Fluorescent and incandescent.

Data compiled by local representatives of Augusta, Bangor and Portland, Maine.



The Silvray 1500 Line — *standard for schools, offices, and libraries and other locations having critical lighting requirements. When used with silvered-bowl lamps, light distribution is totally indirect. Easy-to-maintain 1500 Line units are available in sizes from 150 to 1000 watts.*

319* California schools install Silvray silvered-bowl lamp fixtures

In California alone, 319 schools have installed Silvray silvered-bowl lighting units in the past 18 months . . . while, throughout the nation, Silvray units are being specified wherever efficient, eye-conserving lighting is required.

Silvray installations are characteristically free from eye-torturing glare — both direct and reflected. Largely responsible for the visual comfort afforded by Silvray luminaires is their use of silvered-bowl incandescent lamps. Functioning as both a light-source and light-control element, they collect and direct light to the ceiling making *it* the primary source of diffused light. The resulting indirect light minimizes shadows and reflected images . . . permits certified efficiencies of 80 - 90%.

Yet, a Silvray installation is within reach of every school building budget. In fact, Silvray equipment — because of its low initial cost, maintained efficiency of light-output and simplified maintenance — is often lower in overall expense than other lighting systems.

• • •

**A partial count of Silvray — and Silvray-licensee — installations made in California schools during the past 18 months. Names will be sent to you upon request.*

Send for complete details — mail this coupon, today.

Smoot-Holman, Inc. of Inglewood, Cal. — west coast licensee.

SILVRAY Lighting, Inc. 104 West Main St., Bound Brook, N. J.

Gentlemen:

Please send me further information on Silvray indirect lighting units. I am particularly interested in lighting for:

☐ offices ☐ schools ☐ commercial buildings ☐ homes

Name _____

Firm _____ Title _____

Address _____

City _____ Zone _____ State _____

(Continued from page 18A)

Installations of Materials and Apparatus. Section 4 is on General Requirements for Wiring Installations. Special installations and equipment are treated in Section 5. Section 6 covers standards for wiring materials and equipment based on the Standards of Underwriters' Laboratories, Inc. It also contains tables and working data scattered throughout the Code itself. The book has 652 pages and is illustrated.

CSA Specification C10-1951 — Large Incandescent Tungsten Lamps (Third Edition), available from the Canadian Standards Association, National Research Building, Ottawa at $1.75 each, details standards and definitions pertaining to large incandescent tungsten lamps, their physical and electrical characteristics and the tolerances permissible in their inspection and testing.

New Light on Your Favorite Subject, is the title of a new educational sound slide film, in color, announced by the Lamp Division, General Electric Co., Nela Park. The presentation, said to feature the correct principles of home lighting in proper relation to various types of residential furniture, consists of 84 frames appearing at an average rate of one picture per ten seconds. Entertaining explanations give scientific data on light and sight in simple terms. The entire presentation takes less than fourteen minutes.

Sponsored by General Electric's Lamp Division in cooperation with the National Retail Furniture Association the film will be distributed throughout that Association for sales training purposes. It will also be made available to electric utilities, trade and consumer groups.

Detailed information on the JH-1 fluorescent mercury lamp is given in a new **4-page booklet, A-6007,** from Westinghouse Electric Corp., Lamp Division, Bloomfield, N. J. In addition to a physical description of the lamp, the booklet provides recommendations as to where the JH-1 is best applied. Comparisons with other light sources and tables of technical and transformer data are also given.

Listen to Mr. Tee-Vee, an 8-page educational pamphlet in "comic book" style, stressing the benefits of proper lighting while watching television has been produced by the Television Committee of the Edison Electric Institute. In addition to proper lighting and proper viewing distance, the booklet contains a full page showing interference patterns which do not require a service call to eliminate. The booklet is available from Edison Electric Institute for $2.00 per 100 copies in minimum lots of 100, with an additional 10 per cent for non-members of the Institute. Orders should be sent to 420 Lexington Avenue, New York 17, N. Y.

Meter Socket Selector, booklet B-5284, available from the Westinghouse Electric Corp., Box 2099, Pittsburgh 30, Pa., gives information to help in choosing the proper type meter socket. Circuit closing provision, terminals, service disconnects, and ordering are also covered.

Information on "how to select" electrical measuring instruments is provided in a 30-page booklet, B4696, available from the Westinghouse Electric Corp., Box 2099, Pittsburgh 30, Pa. Seven basic selection factors are explained; types of instruments available in each major classication are listed on a full-page check chart; and four typical selection problems are solved. Complete lines of portable, switchboard, panel, recording and socket instruments are described and illustrated and functions of each are explained.

A new booklet covering the subject of higher-voltage wiring for office buildings with the fluorescent lighting controlled by low-voltage remote-controlled switches, has been published by the Construction Materials Division of General Electric Co., Bridgeport 2, Conn. The important phases of this new application of higher voltage are all covered in the booklet, including a discussion of the savings of installed cost of equipment and wiring and the important savings of critical materials that are effected by use of this system.

NEW MEMBERS

At the meeting of the Council Executive Committee held in New York City on January 10, 1952, the following were elected to membership:

ARIZONA CHAPTER

Member:
Kiger, Glenn, City of Phoenix, Phoenix, Ariz.

BRITISH COLUMBIA SECTION

Member:
McRae, K. J., J. H. McRae Co. Ltd., Vancouver, B. C.

CAROLINAS CHAPTER

Associate Member:
Kirkpatrick, W. M., General Electric Co., Charlotte, N. C.

CONNECTICUT SECTION

Members:
Gorman, W. D., Hartford Electric Light Co., Hartford, Conn.
Wilder, Bolton, Court Butler Ltg. Inc., Meriden, Conn.

Associate Members:
Ferguson, L. J., Albert Kahn, Windsor Locks, Conn.
Plimpton, H. P., General Electric Co., New Haven, Conn.

CORNHUSKER CHAPTER

Associate Member:
Johnson, M. B., Consumers Public Power Dist., Columbus, Neb.

EASTERN PENNSYLVANIA CHAPTER

Associate Members:
Brown, C. R., Lehigh Electrical Supply Co., Bethlehem, Pa.
James, Richard, III, Sylvania Electric Products Inc., Philadelphia, Pa.
Pfeiffer, C. J., Jno. E. Graybill & Co., York, Pa.

FLORIDA CHAPTER

Associate Member:
Woodhead, F. A., General Electric Supply Corp., Tampa, Fla.

GEORGIA SECTION

Associate Member:
Kimbrough, T. E., Jr., Redstone Arsenal, Huntsville, Ala.

HEART OF AMERICA SECTION

Associate Member:
Carmichael, T. H., Sheffield, Murray Electric Co., Kansas City, Mo.

INDIANA SECTION

Associate Member:
Mott, K. N., Municipal Electric Light & Power Plant, Richmond, Ind.

IOWA SECTION

Member:
Stevenson, D. B., Jr., Stevenson & Pulley, Des Moines, Ia.

Associate Member:
Welton, M. M., 333 Grand Ave., Des Moines, Ia.

MARYLAND SECTION

Associate Member:
Allen, P. K., General Electric Co., Baltimore, Md.

MEXICO CHAPTER

Associate Member:
Aguirre, J., Constructora Electrica, S. A. de C. V., Mexico, D. F.

MICHIGAN SECTION

Member:
Parks, J. T., Holophane Co. Inc., New York, N. Y.

MILWAUKEE SECTION

Associate Members:
DeGroot, Al, Al De Groot Inc., Green Bay, Wisc.
Petzold, G. D., Wisconsin Electric Power Co., Racine, Wisc.
Reynen, W. M., Morley-Murphy Co., Green Bay, Wisc.

MONTREAL SECTION

Member:
Thompson, P., Northern Electric Co., Montreal, Que.

NEW ENGLAND SECTION

Member:
Quintiliani, Edmund, Wheeler Reflector Co., Boston, Mass.

Associate Members:
Connell, J. V., Sylvania Electric Products Inc., Salem, Mass.
Krenn, J. M., Sylvania Electric Products Inc., Salem, Mass.
La Pelle, W. B., Sylvania Electric Products Inc., Salem, Mass.
Smith, H. E., Wyman-Gordon Co., Worcester, Mass.

NEW ORLEANS SECTION

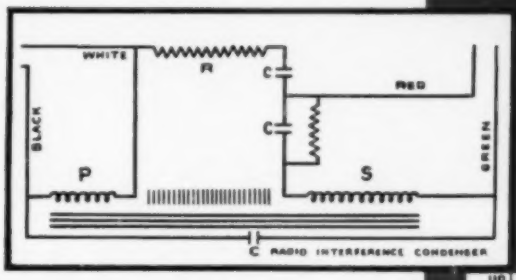
Associate Member:
Muhs, Geo. C., Jr., EACO, Inc., New Orleans, La.

(Continued on page 31A)

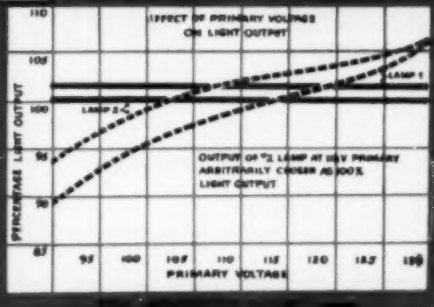
the only ballasts with all three . . .

❶ COOLER OPERATION

Only SOLA Ballasts have the patented ventilated capacitor compartment. The temperature rise on the condenser of the SOLA Sequenstart* Ballast 608-407, for example, is only 18°C. This exceptionally low temperature is due to the insulating action of the ventilated capacitor compartment which isolates the core structure and capacitor with a buffer of circulating air. Cooler operation greatly prolongs ballast life by practically eliminating capacitor failures.



❷ MORE LUMENS PER WATT


EFFECT OF PRIMARY VOLTAGE ON LIGHT OUTPUT
PERCENTAGE LIGHT OUTPUT
LAMP 1
LAMP 2
OUTPUT OF #2 LAMP AT 105V PRIMARY ARBITRARILY CHOSEN AS 100%
LIGHT OUTPUT
PRIMARY VOLTAGE

❸ CONSTANT LIGHT OUTPUT

Only SOLA Ballasts have the patented constant wattage resonant circuit. Light output will not vary with line voltage fluctuations when fluorescent luminaires are equipped with SOLA Constant Wattage Ballasts. They deliver a constant supply of energy to the lamps within ±1.5% regardless of line voltage variations from 100-130 volts. This exclusive SOLA constant wattage characteristic is based on the famous patented SOLA Constant Voltage Principle.

*Made under one or more of the following patents: 2,143,745; 2,212,198; 2,346,621 and patents pending.

A folder is available tabulating the follo[wing information] about SOLA Fluorescent Lamp Ballasts: LAMP size, current and [ballast] BALLAST wiring diagrams, watt-age loss, and dimensions; and operati[ng] line voltages. You are invited to write for a copy. Request Bulletin C-PFL-144.

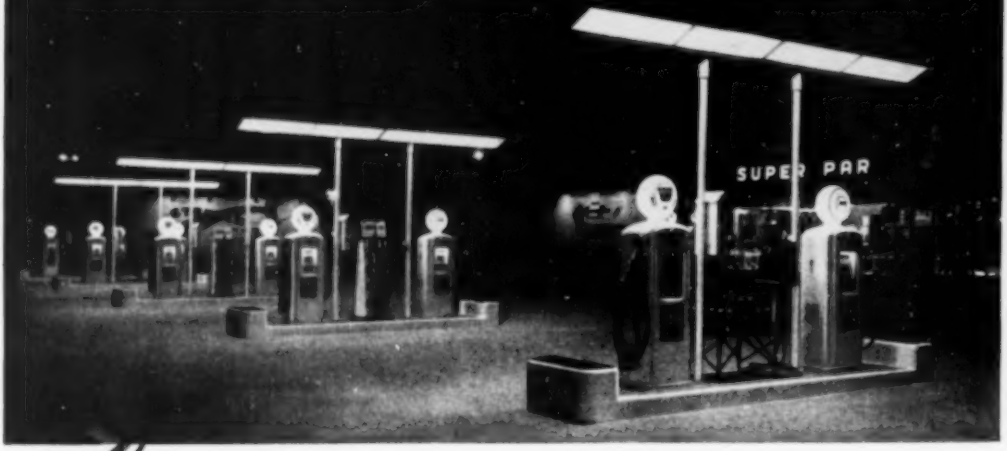
SOLA Sequenstart Constant Wattage BALLASTS

Transformers for: Constant Voltage • Fluorescent Lighting • Cold Ca[thode] Lighting • Airport Lighting • Sign Lighting • Luminous Tube Sign[s] Oil Burner Ignition • X-Ray • Power • Controls • Signal Systems • etc. •

The First Overhead Fluorescent Lighting Unit

Expressly Designed for...

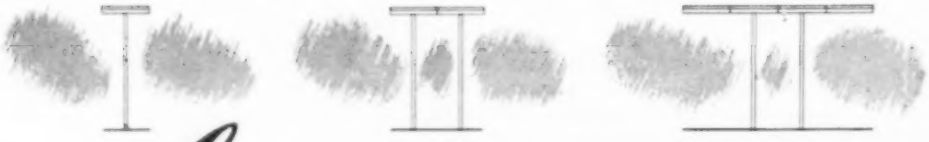
ISLAND LIGHTING



the Leader "Station Master"

New, but tested and proved! The Station Master makes sales z-o-o-om to fantastic new highs! Specifically designed to deliver high intensity of light at the selling zone, without creating a barrier of glare. Provides truly inviting lighting for the motorist, and reduces service-time per car. The Station Master is Leader's answer to the need for modern glare-free lighting and efficient island illumination. No station is too small—or too large—to be deprived of Station Master sales-stimulating illumination.

AVAILABLE IN SIZES OF FOUR — EIGHT — OR SIXTEEN FEET



Sold and installed by the better electrical dealers and contractors

Leader *America's No. 1 Lighting Equipment Manufacturer*

LEADER ELECTRIC COMPANY • 3500 North Kedzie Avenue • Chicago 18, Illinois
Leader Electric—Western: 800 One Hundredth Avenue, Oakland 3, California
Campbell-Leader, Ltd.: Brantford, Ontario, Canada

Cut costs for your customers with G-E WATCH DOG* STARTERS

When you specify no blink G-E Watch Dog starters, you protect your recommendations by cutting costs for your customers for years to come.

Give every recommendation this low-cost extra for more comfortable seeing—for customer savings.

specify fixtures that display the Watch Dog tag

Many manufacturers are pointing out Watch Dog starters and the famous red reset button with the Watch Dog tag. Look for it when you buy. Section Q12-287, Construction Materials Division, General Electric Company, Bridgeport 2, Conn.

*Registered Trade-mark of General Electric Company

EXTRA STARTER LIFE—

Because Watch Dogs turn lamps OFF when aging makes them blink, Watch Dogs give as much as five times the service offered by ordinary starters.

You can put your confidence in—

GENERAL ELECTRIC

ART METAL

has developed a lot of new ideas in

INCANDESCENT LIGHTING

ADVANCED DESIGN
ART METAL
NEW PRODUCT RELEASE
A.I.A. FILE 31F7
On pages like this, beginning March 1st, ten new categories of products that will set new standards will be released.
Write for these new releases and a leather bound catalog.
INCANDESCENT UNIFIED LIGHTING
Unified in Design Characteristics
THE ART METAL COMPANY
CLEVELAND 3, OHIO
Manufacturers of Engineered Incandescent Lighting
A.I.A. FILE 31F7

For visual signals, for controlled distribution of light, for colored floodlighting effects, for intense concentration of light in beams or for uniform coverage of limited areas, Kopp lenses, color filters or roundels give the control and modification desired. Whether it be a traffic signal lens designed to concentrate the beam in the area where it is most easily perceived by motorists, or an indicator light to warn a housewife that one of her appliances is in operation —Kopp engineers can develop the most effective design, and Kopp craftsmen produce parts that are accurately made and dependably uniform in color, dimensions and transmission value.

Our well-staffed, modernly-equipped laboratory is prepared to study your requirements and develop designs that will meet your most exacting specifications.

KOPP GLASS

KOPP GLASS, Inc.
SWISSVALE, PA.

NO OBJECTIONABLE HUM

Due to advanced Engineering and Precision Manufacture

CERTIFIED

LIGHT IN WEIGHT

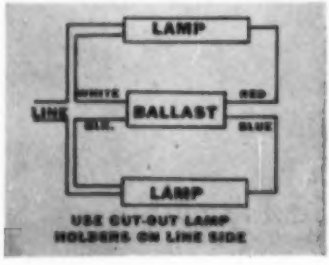
JEFFERSON ELECTRIC

NEW JEFFERSON 254-511 BALLAST

(Photo Courtesy of Curtis Lighting Inc., Chicago, Illinois)

for Series Operation of Two 96T12 Lamps 430MA

White and red leads connect to one lamp,—black and blue to the other.

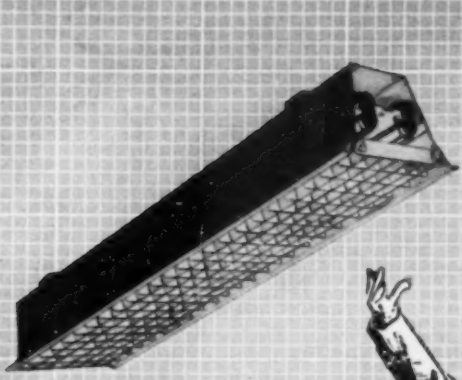


• Specialists for over 35 years in the design and manufacture of transformers and ballasts, Jefferson engineering design, research, and experimental work has been constantly directed to achieve the highest uniform quality. Equally important are Jefferson's facilities and skills gained through long experience in making superior electrical products.

The new Jefferson Series Sequence Ballast meets all requirements of the proposed American Standard Association Test Specification C82.1. It is cooler operating, delivers full rated wattage to the lamps with low watt loss, operates with no objectionable hum, and assures full brilliancy from both lamps. Positive starting is provided at voltages as low as 106 volts—*with no detrimental effect on lamp life.*

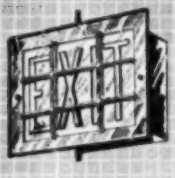
JEFFERSON ELECTRIC COMPANY Bellwood, Illinois

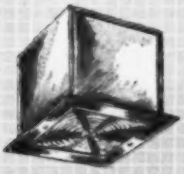
In Canada: Canadian Jefferson Electric Co., Ltd., 384 Pape Ave., Toronto, Ont.



KIDS ARE KIDS

... and usually they're unpredictable. But you can always predict how a Gruber fixture will perform ... because every unit is backed by reliability. It's the reliability that comes from constant checking ... of construction ... of finish ... of wiring. It's the reliability that comes from using heavy gauge metal ... the finest electrical components ... phosphortized undercoat ... high baked finish. And you'll realize the importance of this reliability when you find how low maintenance costs will be when Gruber fixtures are used. On your next job ... specify GRUBER with confidence ... and be sure.





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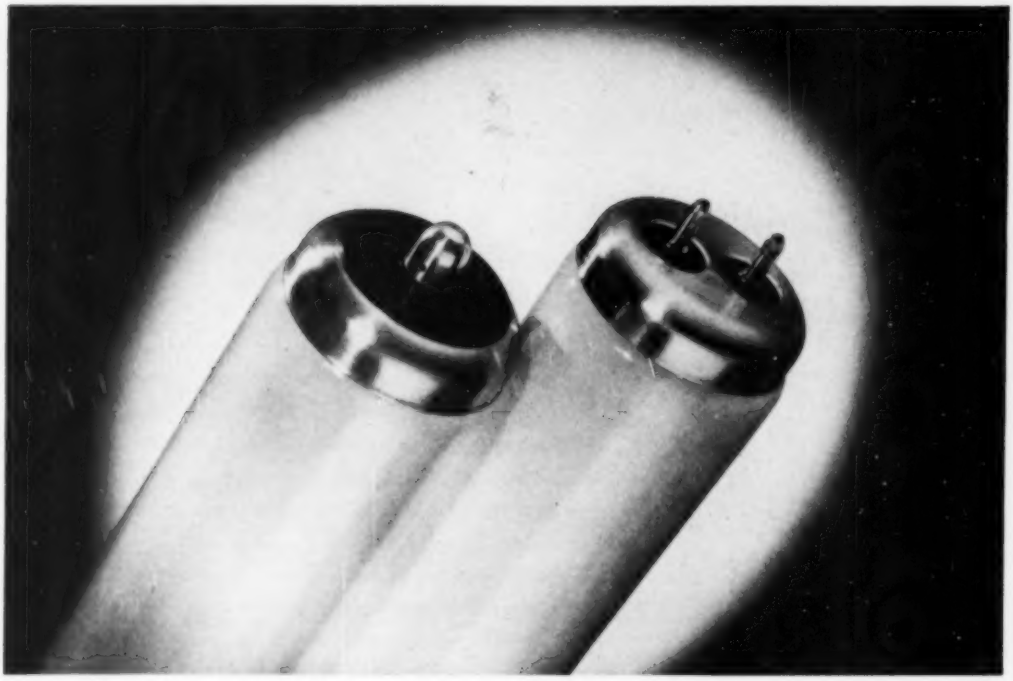
This is one . . . found in G-E lamps, of course!



THE ends of these fluorescent lamps are aluminum. Rough handling doesn't crack them. Cold can't shrink them enough to make them crack the glass tube. They can be heated hot enough to make a tighter seal. They eliminate one reason why fluorescent lamps sometimes fail before they should. They're on G-E lamps, of course. This is one of many basic differences that make General Electric your customers' best buy in fluorescent lamps.

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2800-square-foot PLEXIGLAS luminous ceiling in Rohm & Haas Company Engineering Building, Bristol, Pa. Corrugated white translucent PLEXIGLAS is mounted wall-to-wall below continuous runs of fluorescent lamps. Upper window glazing is corrugated gray PLEXIGLAS, for prevention of sky glare.

ENVIRONMENTAL LIGHTING . . . With a PLEXIGLAS Luminous Ceiling

For *environmental* room lighting, the whole field of view must be in brightness balance . . . as in this drafting room with its PLEXIGLAS luminous ceiling.

The surface brightnesses of the ceiling, the walls, and the window areas of this room are less than three times as bright as the paper on the drawing boards. Note how these surfaces produce a field of uniform brightness in which there are no eye-fatiguing light-to-dark contrasts.

An average illumination of 118 footcandles is provided through the PLEXIGLAS diffusing panels, without objectionable direct glare from the large-area ceiling surface.

PLEXIGLAS acrylic plastic offers other advantages as a diffusing medium. Because it is rigid, light in weight, and strong, PLEXIGLAS can be handled easily and safely during installation, cleaning, and relamping operations. And because it is highly resistant to breakage and discoloration, it gives long, low-maintenance service.

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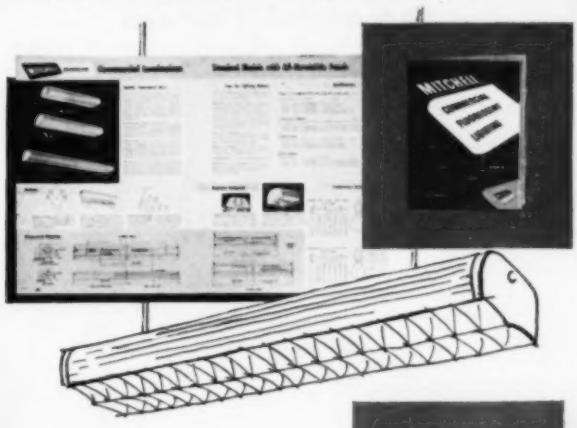

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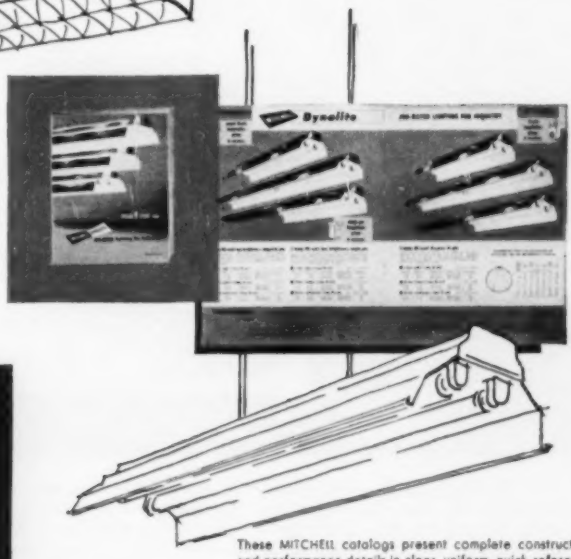

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These MITCHELL catalogs present complete construction and performance details in clear, uniform, quick-reference style. You get application data, specifications, features, dimensions, curves for every model—for quick, proper specification and installation planning.

Where Quality Counts—
SPECIFY MITCHELL!

Quality is not just a word—it is an important tangible that can be seen and measured in every MITCHELL lighting unit. These superbly engineered fixtures are built to the most exacting standards for easy, time-saving installation—for low-cost maintenance—for dependable, long-life, efficient performance. Where *quality* with sensible initial cost must be your most important considerations, in either commercial or industrial lighting—be sure—specify MITCHELL!

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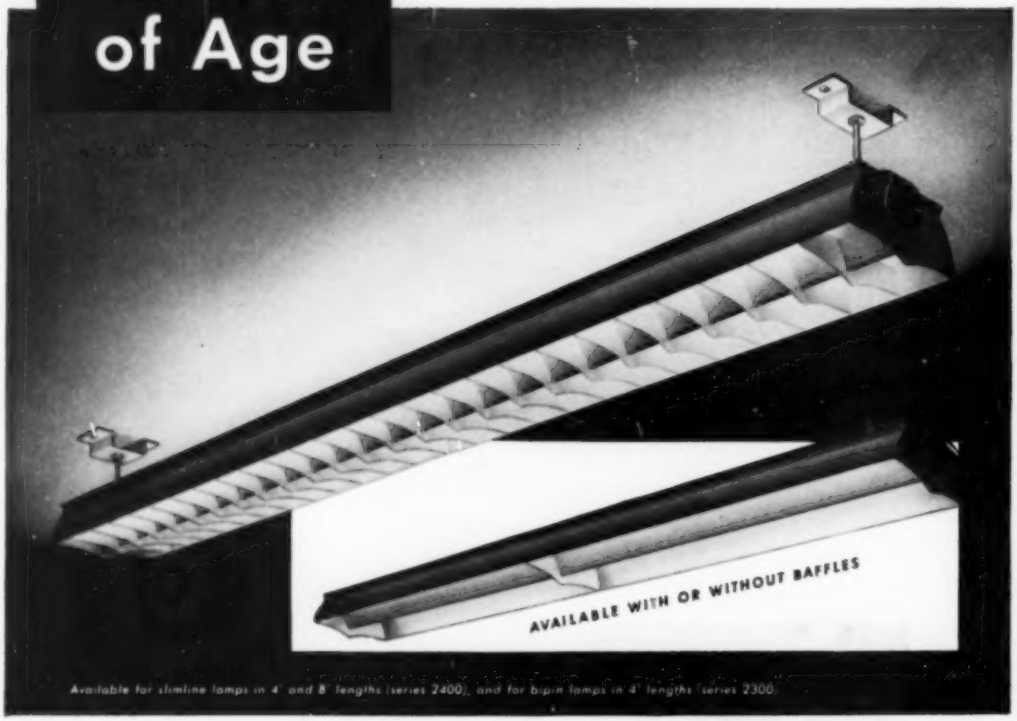

Available for slimline lamps in 4' and 8' lengths (series 2400), and for bipin lamps in 4' lengths (series 2300)

HERE IT IS — the new LITECONTROL Industrial Unit that provides "white collar lighting for shop coat areas."

Minimum waste light . . . maximum lighting efficiency — This unit, employing general diffuse design, provides vent areas at the roof of the hood. Light is not "trapped" and thereby wasted as in older hood types, but instead is reflected through the vent to the ceiling and thence again to the working area *where it is needed.*

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Maintenance minimized . . . mounting simplified — There's no maintenance worry with this LITECONTROL advance design. Lamps and starters can be easily replaced without disturbing baffles. Smooth curved sides can be wiped clean without cloth-snagging . . . no inaccessible dust corners. Diffuse design also helps keep interior of fixture clean through convection currents and overhead "escape hatch" for dust.

Mounting, too, is easy. Suspension mounting is recommended for peak performance, but provision is made for other methods where preferred or necessary.

Consult your lighting specialist . . . and write for free booklet today — A consultation with your lighting advisor . . . or with your nearby LITECONTROL Representative will save you time, money and trouble. If you are planning on new lighting for your factory, call on him today . . . and write today for your free copy of our new booklet: "Industrial Fluorescent Lighting by LITECONTROL."

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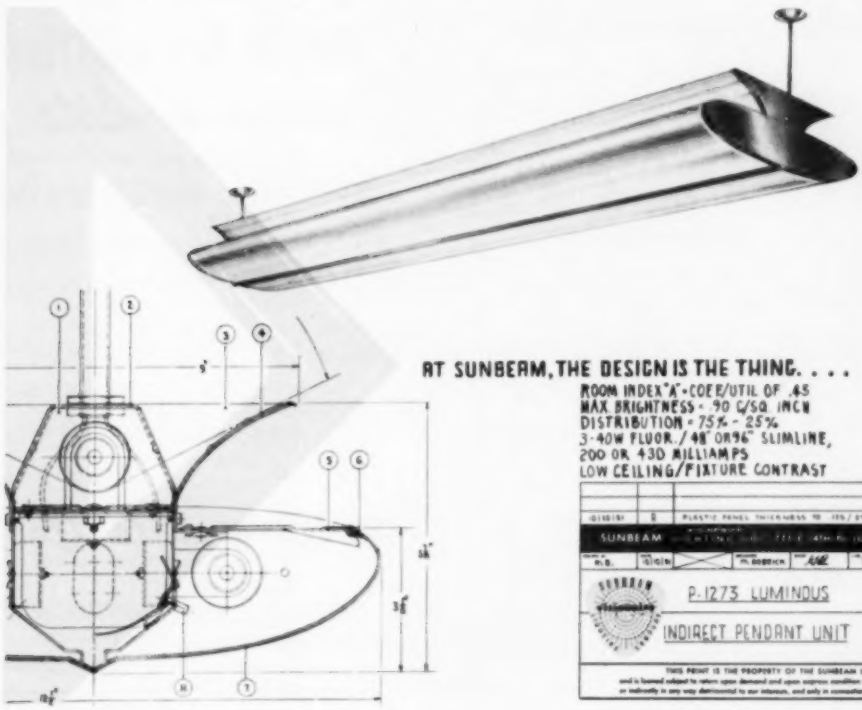
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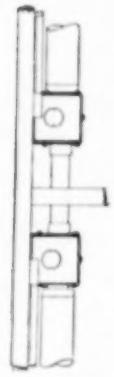

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If you can allow 2" x 2¼" . . . if you can run 4', 6' and 8' lengths between turns or gaps, you can now use standard relampable slimline where formerly only luminous tubing would fit. One remote ballast box required every 32'. All General Electric equipped.

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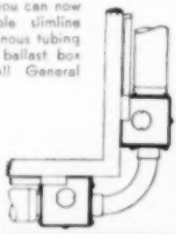

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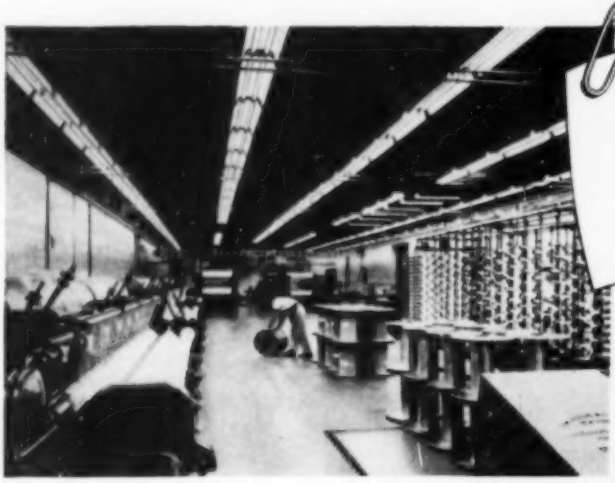

Photographic record shows why Sylvania Fluorescent Lighting speeds production ... saves big money for Southern Mill

Looking for ways to cut costs? Here's a Sylvania Fluorescent Lighting Installation that does just that for the Deering-Milliken Mills in South Carolina.

Note the clean, clear lighting atmosphere in the above photo. Sylvania tubes and fixtures furnish a lighting level practically triple that obtained from former lighting units. As a result, mill authorities estimate, the saving realized in production costs, time, and the elimination of waste *will completely pay for this efficient installation in just three years time.*

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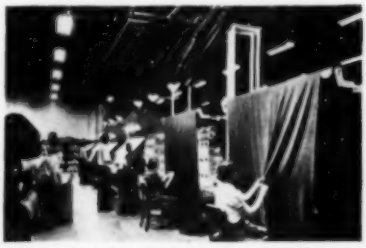
Sylvania now offers fixtures for every industrial need . . . equipped with 2, 3, or 4 tubes . . . standard or instant start. Ask your secretary to mail the coupon for full information TODAY!

$1500 Saved Here. This unique inspection method uses 24 forty-watt Sylvania fluorescent tubes and a luminous panel. Mill engineers estimate this Sylvania-designed unit provides a saving of $1500 per year.



Inspection speeded here. Excellent use is made of the flexibility of Sylvania Fixtures. Hung at an angle over the cloth they eliminate need for slow, costly hand portable droplights and greatly speed inspection. Another big saving with Sylvania.

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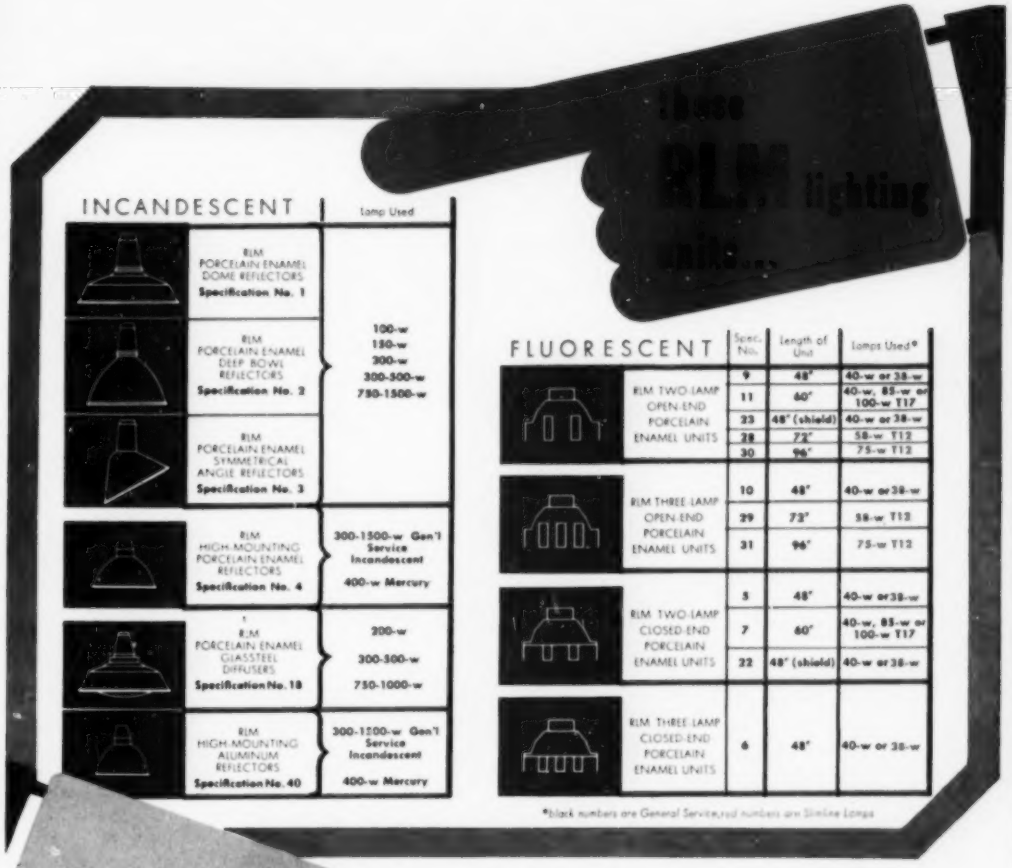
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28 72" 58-w T12
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7 60" 40-w, 85-w or 100-w T17
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Defense production demands the highest type of lighting performance to meet the wide range of seeing tasks, varied atmospheric conditions and difficult seeing conditions found today, as American Industry shifts into high gear. To meet these needs economically and dependably, the emphasis is on *uninterrupted* performance. Therefore it is important to specify units that can be depended upon to provide and *sustain* rated light output over years of service.

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Shown here is a chart, listing the 34 different industrial lighting units for which the RLM Standards Institute has established specifications covering construction, finish, reflector design, ballasts and uniform quality. The Institute is currently engaged in the development of new specifications and revision of present standards in its effort to keep abreast of the latest advancements in illuminating engineering. To make certain of lighting performance that is the kind needed for defense production, specify lighting units certified to conform to RLM Standards of Quality.

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